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PROCEEDINGS OF THE SIXTH ANNUAL DEPARTMENT OF DEFENSE PROCUREMENT RESEARCH SYMPOSIUM (6th).

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ARMY PROCUREMENT RESEARCH OFFICE
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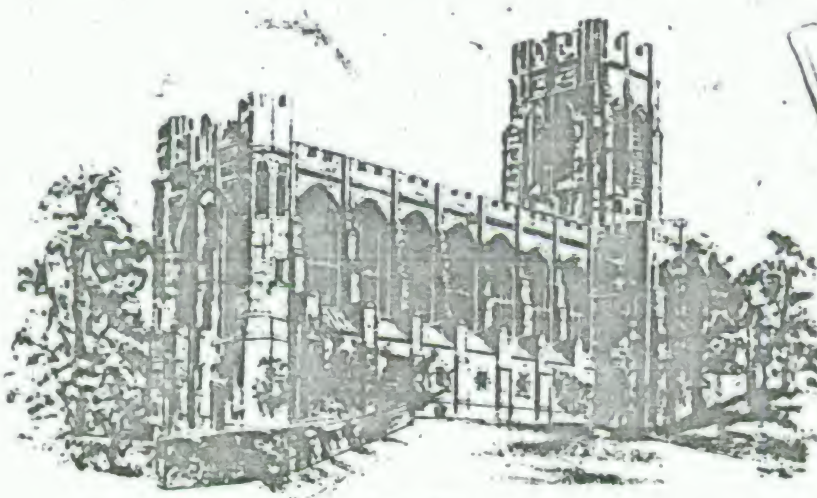
"TRANSLATING PROCUREMENT RESEARCH INTO ACTION"



Cadet Chapel

Held at
US MILITARY ACADEMY • WEST POINT, NEW YORK

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OFFICE OF THE DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING
WASHINGTON, D.C. 20301

PREFACE

The Department of Defense Procurement Research Coordinating Council is proud to have sponsored the 6th Annual DoD Procurement Research Symposium. These proceedings reflect three full days of brisk activity - of 50 different speakers, lively discussions, and general professional growth, not to mention good food, fine company, and outstanding West Point hospitality. We are all indebted to the Commandant and the USMA Staff for their efforts.

We, of course, want to capture part of that activity and share it with those in the acquisition and research committees who could not attend. I believe that much of the work described will endure and hope that this document will become a valuable part of the library of both the procurement researchers and the procurement managers.

The Council is indebted to the speakers and participants who made this meeting a success. We also owe special thanks to the Army Procurement Research Office (APRO) who developed the symposium and gathered these proceedings and to our host, the United States Military Academy.

John H Kunsemiller
JOHN H. KUNSEMILLER
Chairman
DoD Procurement Research
Coordinating Council

Additional copies of the Proceedings may be obtained by writing:

US Army Procurement Research Office
US Army Logistics Management Center
Fort Lee, Virginia 23801

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WELCOMING ADDRESS

LTG Andrew J. Goodpaster
Superintendent, US Military Academy
West Point

May I extend a very warm and cordial welcome to all of you to the United States Military Academy. As you know, I do this on the strength of my having been here for about one week myself. It's a great deal of pleasure to welcome you and your ladies to this 6th Annual Department of Defense Procurement Research Symposium. I think you will agree that you can hardly have chosen a more beautiful and historical location or a more delightful day. As I was saying as we walked over, we don't like to dispense too many of these. We like to save a few of them because there comes a time when we know that we'll need them.

Your concern is with procurement. More specifically with procurement research. And even more specifically, translating procurement research into action. It's a concern that we all share, each in his or her own way.

Government procurement, simply stated I suppose, is the act of obtaining, normally from some commercial source, the necessary supplies, equipment or material to support all the Department of Defense activities. As we know there are many activities, ranging from the highest echelon of command to the lowest user level which must be supported as efficiently and as economically as possible, during both peace and war. That's a great charge and a great responsibility. And particularly as the boundaries of technology and weapon systems and intraspace travel are pushed out further, the method of procuring the overall support for these programs and the systems must stay abreast. That is a heavy charge, because any program moves only as fast as its least developed element. The method of obtaining total system support must therefore not lag behind or hold up the rapid progress in other fields of technology.

Although I don't claim to be an expert in your particular field, I would suppose that research in your field, in its basic form, is an ongoing challenge of seeking the proper procurement method, whether it be new or old, or a mixture of the two required to meet the needs of today using the strengths of the past with flexibility for tomorrow. The challenge to a group like this, I believe, is to achieve a procurement methodology or a set of procurement measures that meet a number of criteria. They must be creditable with the industrial sources, flexible to meet current and future Department of Defense requirements, capable of being understood and being implemented at the lowest level procurement activity, and capable of opening the communication links and keeping them open between the user activity and the procurer. I would add to that, that they should be economical to implement and administer and they should be within the intent of the statutes that govern the expenditure of taxpayers money. A goal for this symposium could then be greater economy through better procurement methods.

Again a welcome to West Point. I hope your stay will be both informative and rewarding. We wish you well in the important task that you're undertaking. Thank you very much.

KEYNOTE ADDRESS

SIXTH ANNUAL DEPARTMENT OF DEFENSE

PROCUREMENT RESEARCH SYMPOSIUM

"TRANSLATING PROCUREMENT RESEARCH INTO ACTION"

BG(P) Jere W. Sharp
Director for Procurement and Production
US Army Materiel Development and Readiness Command

Good Morning ladies and gentlemen,

On behalf of the Army Materiel Development and Readiness Command and its Commanding General, General Jack Guthrie, I am pleased to welcome you to this 6th Annual DOD Procurement Research Symposium and I feel strongly that the discussions that will ensue here will enhance the "Translation of Procurement Research Into Action," the theme of this year's symposium. As we learn about completed and on-going research projects and through discussions of vital relationships between the procurement research and operational spheres, we should be able to generate ideas and stimulate actions which will visibly improve the efficiency of the Government's procurement system.

I am pleased that this year's symposium is not restricted to procurement and acquisition research conducted by the military services, but that other Governmental agencies, industrial concerns, and academic interests are also well represented. Thus, this year's symposium will not only provide for a greater breadth of technological transfer of improved procurement methods and management techniques, but it will set the stage for wider based procurement research symposia in years to come. Future conferences in this series will be conducted on a broader governmental basis, probably by the Federal Procurement Institute, and have an even wider participation than in this and past years.

I have a double pleasure being with you today. The first is returning to West Point where I spent 8 of my first 14 years in the Army, 4 as a cadet, and 4 as an instructor in the Department of Mechanics. The second is a result of my present job. I have under my operational control a research organization to pursue the development of new procurement concepts as well as to assist me in the performance of my procurement operational and management duties. The pleasure of the first will be over in a few days, except of course for the renewed memories and stimulating experiences. But the pleasure and challenge of the second--I am just beginning to experience. How I view my role in this new-found responsibility is what I'm going to relate to you this morning.

When I was selected as Director for Procurement and Production for the Materiel Development and Readiness Command, one of my first actions was to review my organization and mission. In addition to the duties and responsibilities assigned to me for directing the procurement and production activities of the Materiel Development and Readiness Command, I found that I was to exercise operational control over the Army Procurement Research Office. I contemplated what my responsibilities would be for exercising this control and how it might relate to my other responsibilities as director of procurement and production activities. From my previous experience as a procurement operator and manager and my academic

exposure as a faculty member, I recognize the need for balance between operational relevance and scientific authenticity in the conduct of procurement research. I realize the two are not incompatible, but the pressures of time sometimes makes the reconciliation very difficult. This year we are homing in on "translating procurement research into action," so I will try to explain how I conceived of the relationship between my responsibilities as a Director of Procurement Policy and Operations and my responsibility to make effective use of our procurement research resource.

To link procurement management with research would normally require a definition of each. But, I believe the managerial understanding of this assembly will enable me to forego a discussion of procurement management. I will, however, offer a brief definition of procurement research, so as to provide you with my perspective of the symposium's subject. And, I shall offer a short definition of translate and action so that I can complete the linkage explicit in our theme this year.

Procurement research is the identification, analysis and development of approaches to the resolution of problems faced by acquisition planners, procurement managers and contracting officials. The actual research process proceeds from problem confirmation through research design, data collection, analysis, and interpretation to development of implementation or operational testing procedures. It is the latter function, implementation, where translating comes in.

The Webster International Dictionary definition of translate is on the viewgraph. It is important to know that in the context of this symposium we mean all of these. It is necessary to translate the scientific, rigorous language of a research report into more common operational terms for understanding and use by personnel working in a less structured environment. The research concepts, objectives, and inferences must be converted to forms compatible with the work situation our procurement operators find themselves in. The improved or new techniques must be moved from the laboratory to the acquisition planning scene or procurement office. Lastly, action is simply "the process of doing; an exertion of power or force." In procurement, this consists of developing strategies and plans, directing and controlling procurement actions, and managing the resources needed to perform these actions.

DEFINITIONS

"Procurement Research"	Identification, Analysis, and Development of approaches to problems faced by acquisition planners, procurement managers, and contracting officials
"Translate"	Turn from one language to another, change to another form, move from one place to another (Webster's International). We mean all three.
"Action"	Process of doing, exertion of power or force i.e., developing plans, directing and executing procurement actions, managing resources

It is the job of all of us here, procurement planners, researchers, managers and operators to collaborate in this translation process.

We might liken the transition process to the "marketing" function. If we compare the "market" to the procurement or acquisition system and customers to managers and operators whose needs include new-found knowledge and products to satisfy the system's needs, then we

see the vital interdependence of procurement research and the market. To varying degrees we share the responsibility for the marketing of procurement research. I don't mean selling, but determining the needs of the procurement system, identifying and directing the resources required to meet these needs, and implementing the results.

"TRANSLATION" AS A "MARKETING" FUNCTION

"M RKET	"TRANSLATION"	"PROCUREMENT RESEARCH"
ACQUISITION SYSTEM	MARKETING MANAGEMENT	SCIENTIFIC INVESTIGATION
Planners	Need Assessment	New Knowledge
Managers	Priority Establishment	New Techniques
Procurement Officials	Resource Management	New Insight
Contractors	Implementation Planning	
	Performance Evaluation	

During the next few days, you will be seeing actual products that have gone through this "marketing" process, ranging from Jim Stansberry's comprehensive effort in developing and introducing a stimulating new profit approach to detailed techniques for measuring procurement workforce productivity and establishing pricing indices. In between, we will witness a wide array of innovative procurement concepts and techniques, all extremely important to the management of systems and materiel acquisition. For the first time in this series, we have a full session on industrial procurement research, giving us an opportunity to compare ideas and procedures in an environment of challenge and cooperation. In one session, we're looking at ourselves to see where we've been, where we are and where we're going. In another, we examine our most important commodity, ourselves -- the procurement professionals. The range as well as the specific content of these research presentations, I believe, demonstrate that there are few limits to areas in which procurement research can assist planning and management.

In addition to the many examples and suggestions for improving research utilization which will be presented here, I'd like to suggest a particular opportunity for promoting translation into action to which we should be giving greater attention.

Without getting them immersed in firefighting, we need to involve procurement research people in the shaping and implementation of our management goals. This involvement on their part can serve to generate fruitful research topics, which not only assures relevance but generates organizational support as well. Theory building is also aided by this association, for the researcher is permitted to work on problems in system context as opposed to isolated procurement issues.

From the other side of the fence I believe we need to make greater use of our battle-hardened procurement managers and operators in procurement research. I know that some of you use these managers and operators to conduct procurement research on occasion, but a systematic approach will yield more comprehensive results. If planned tours of duty are impractical, assignment to limited part-time projects still provides a valuable stimulus to the translation process. People who have helped form research objectives, designs, and analyses plans are in a substantially better position to assess performance and implement action than those who receive results of research cold.

OPPORTUNITIES FOR ACCENTUATING THE TRANSLATION PROCESS

Use procurement research personnel in shaping and implementing organizational goals:

Generates Fruitful Topics

Gains Organizational Support

Aids Theory Building

Use manager and operators in procurement research:

Enhances Performance Indicator

Speeds Implementation

Insures Advocacy

The opportunities for improved communications and understanding afforded by reciprocal use of researchers and manager/operators in each other's environment far outweigh the administrative difficulties associated with the assignments. We've tried it on a limited basis, and it works. This series of symposia has generated a tremendous amount of cross-functional understanding and cooperative arrangements; but, in between meetings we can enchance the research/action ratio even more by inducing greater cross-usage of our personnel within organizations.

Having underlined the essential relationship between procurement research and procurement action, I feel constrained to offer a note of caution. We can translate all we want and cooperate to the utmost, but if the results of a procurement research project do not meet the system needs, we must recognize this for what it is. The real problem may defy current solution, the research may be inadequate or the implementation may be improper. But, whatever, we must avoid the beartrap of expecting that all research will lead to action.

I know all of you know or have heard this caveat before, but with our theme this year being on results, I think the message bears repeating.

We may well be standing on the threshold of a new era in government procurement. A top level executive office of procurement policy has been established, a federal institute for procurement is being set up, and Congress and the private sector are challenging governmental procurement to improve its procurement practices and find new cost-effective ways of doing business. Procurement research may be the catalyst for us to meet the challenge and fulfull the promise of the new organizational arrangements.

NEW ERA?

Top Level Executive Policy Office

Federal Procurement Institute

Congressional/Public Challenges

Procurement Research - The Catalyst

The next few days should go a long way in moving us to a better understanding of important procurement concepts and methods and alerting us to opportunities for using research to improve procurement action. I certainly intend to take advantage of it and I'm sure you will too. Thank you.

DOD PROFIT POLICY - IMPLEMENTING PROCUREMENT RESEARCH RESULTS

BG(P) James W. Stansberry
Deputy Chief of Staff
Air Force Systems Command

BG Stansberry's paper is not available for publication: His presentation was based on lessons learned from Profit '76, a major DOD procurement research project. As a result of Profit '76, General Stansberry formulated some "Keys to Success" for translating procurement research efforts into positive action and presented these insights to the symposium audience. The following are, very briefly, the main points of his presentation.

The first key to success is to work on real problems. Resources are too limited for the procurement research community to concentrate its assets on "non-problems" that may be very interesting but mean nothing to one's particular organization.

The next key to success, General Stansberry believes, is that if one is ever going to do substantial research, it is important to have a charter giving oneself authority and responsibility which is signed by someone important. This enables the researcher to avoid the bottleneck often encountered when dealing with any bureacratic organization.

Thirdly, it is necessary to find some very talented people and generate some enthusiasm. Having the best people do research will eventually improve the whole process of how DOD "does business."

One of the most important keys is to plan well before starting a job. The essence of getting anything done is to lay out a good plan and check it carefully before beginning work.

Another key to success - one in which General Stansberry demands when he is in charge of a project - is to involve the people in the field who actually do the job. They can offer unique and valuable insights into the real problems affecting their jobs.

Using the library builds up an authoritative data base and precludes the researcher from doing work that has already been done and is therefore, a key to success.

A seventh key to success for the procurement researcher is to allow those who hold opposing biases to examine and attack the numbers and data that he has gathered. This serves as an objective check against mistakes that may have been made and familiarizes one with the "other side."

Creating a Climate of Acceptance by "steering" the policy maker toward one's conclusions is also a significant key to success. A climate of acceptance can enable the researcher to make others realize that their conclusions are not necessarily as they think.

For the project manager, an obvious but very necessary key is to become heavily involved in the project so as to know and understand the details. The manager should at least be able to debate the data with his critics.

General Stansberry believes that one of the weakest areas of procurement research is marketing. Unless the research work causes some changes in the real world, it's useless. Therefore, it is necessary for the researcher to actively market his product once he has finished his report.

Many times, gaining anything substantial involves a degree of risk. In order to make changes, which is a goal of procurement research, it is important to take a few chances, which is General Stansberry's last key to success.

COST GROWTH

STUDY OF FACTORS LEADING TO CHANGES IN COST ESTIMATES ON SELECTED MAJOR DEPARTMENT OF DEFENSE AND NATIONAL AERONAUTICS AND SPACE ADMINISTRATION DEVELOPMENT SYSTEMS

Dr. Richard J. Trainor
Director of Systems Review and Analysis
Office of the Deputy Chief of Staff for
Research, Development and Acquisition, US Army

Dr. Trainor spoke extemporaneously on his subject and did not submit a paper per se. The following abstract and charts should give an idea of his talk:

The major weapon and space systems developed and produced by the aerospace industry are at the world's technological forefront. The aerospace industry and government use the very best talent to manage the acquisition process. In spite of this, the major system acquisition process continues to be characterized by substantial cost growth and schedule slippage. The development phase of the acquisition process is becoming increasingly important and is the subject of this study.

The study of the causes of cost growth has been approached from several aspects. A review of the literature and examination of current management practices provided one focus. This paper will cover the multiple and highly interrelated causes of cost growth. It will examine the cost growth of nine DOD and NASA weapon and space systems.

And lastly the paper will discuss the development of descriptive and predictive models of the development process. The descriptive model is oriented toward description of the impact of a change in management strategy on the cost, time, and risk associated with system development. The predictive model, a derivative of the descriptive model, attempts to estimate the total cost of developing a system based on data available early in the system's development cycle.

SYSTEM COST GROWTH IN DEPARTMENT OF DEFENSE AND NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

OUTLINE

- DEFINITION(S)
- RECENT CASE HISTORIES
- PRINCIPAL CAUSES OF COST GROWTH
- RESEARCH PROBLEMS
- SUMMARY

COST GROWTH DEFINITION(S)

VARIATION IN COST WITH RESPECT TO:

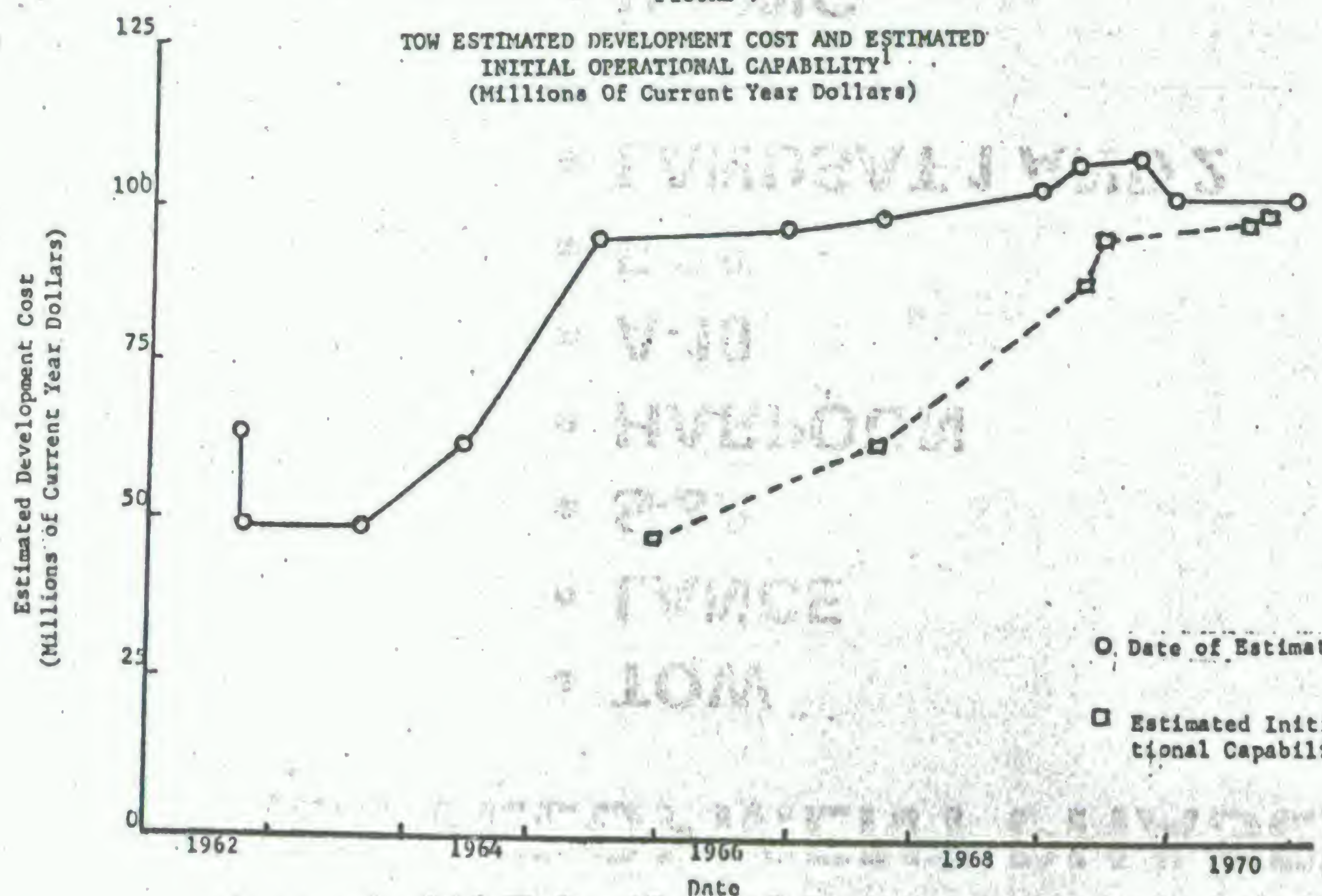
- CONTRACT
- THE SYSTEM REPLACED
- CONTROLLABLE COSTS
- EXCLUDING OVERHEAD
- THE 300TH SYSTEM
- THE ESTIMATE AT ENTRY INTO ED
- THE ESTIMATE AT PROGRAM INITIATION

RECENT CASE HISTORIES (DEVELOPMENT PHASE)

- TOW
- LANCE
- S-3A
- HARPOON
- A-10
- E-3A
- LANDSAT 1 AND 2
- OSO-I
- VIKING

FIGURE 9

TOW ESTIMATED DEVELOPMENT COST AND ESTIMATED INITIAL OPERATIONAL CAPABILITY[1]
(Millions Of Current Year Dollars)



[1]Includes support of night sight and electronic counter-countermeasures.

FIGURE 10

LANCE ESTIMATED DEVELOPMENT COST AND ESTIMATED INITIAL OPERATIONAL CAPABILITY (Millions Of Current Year Dollars)

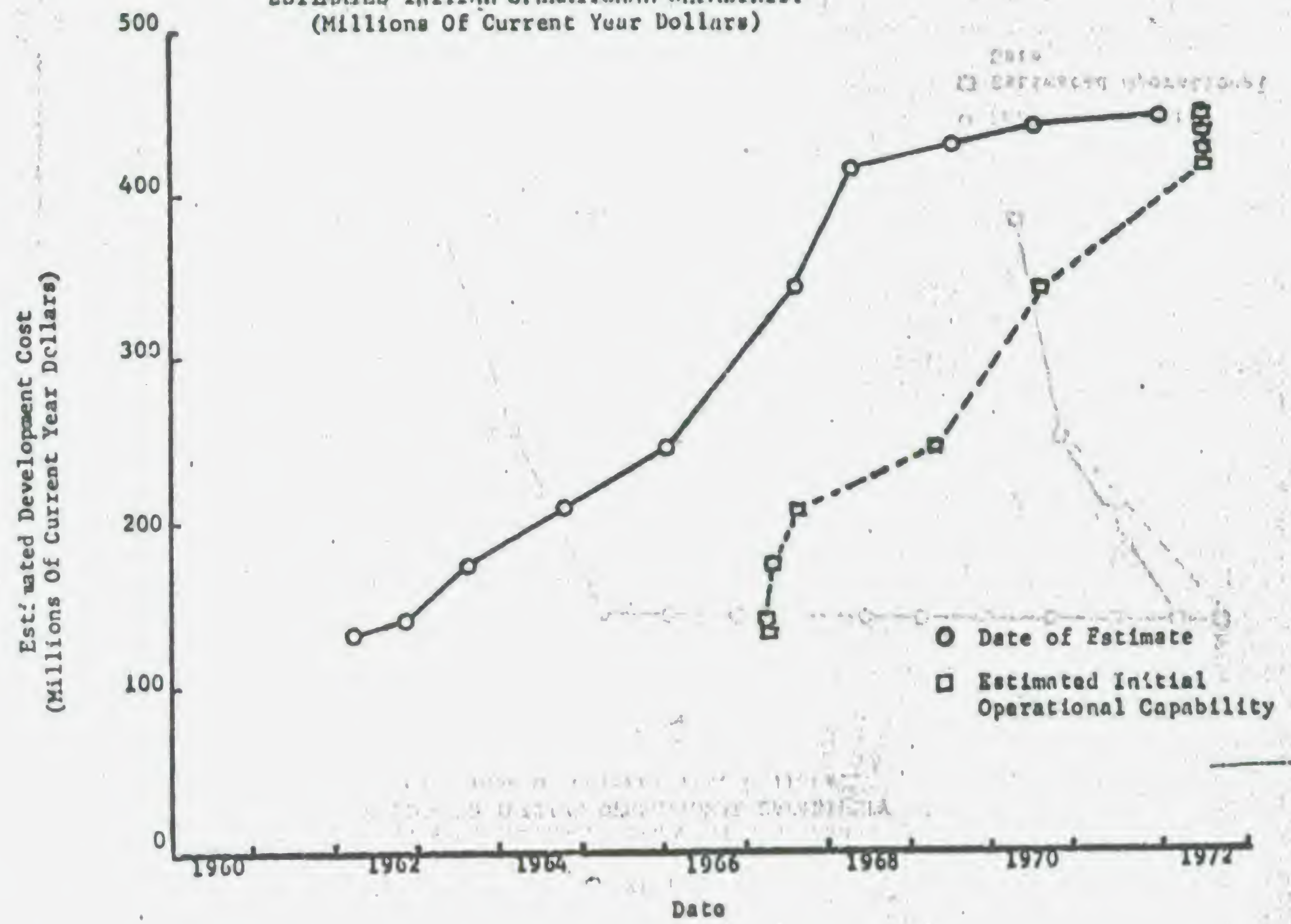


FIGURE 11

S-3A ESTIMATED DEVELOPMENT COST AND ESTIMATED INITIAL OPERATIONAL CAPABILITY
(Millions Of Current Year Dollars)

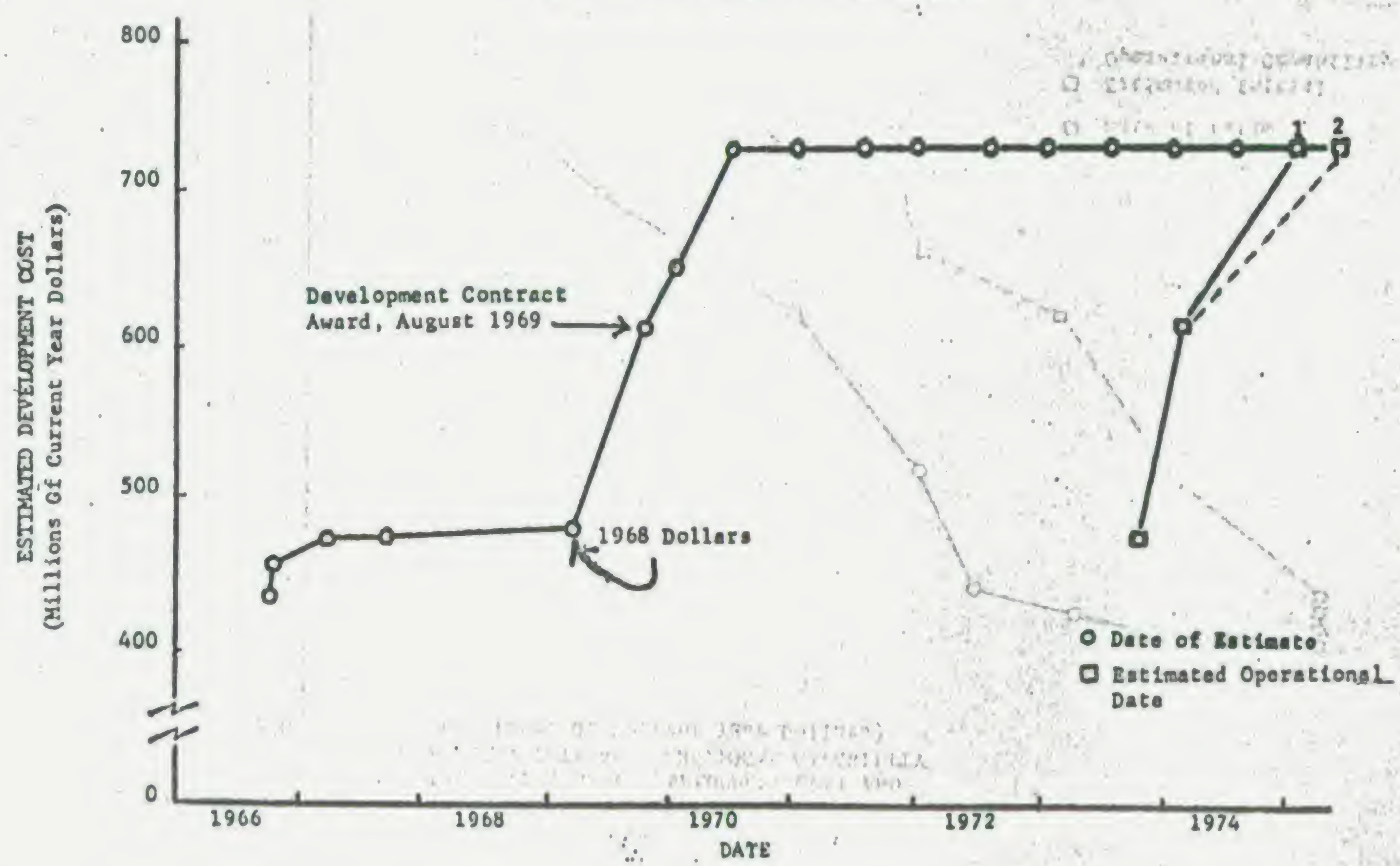
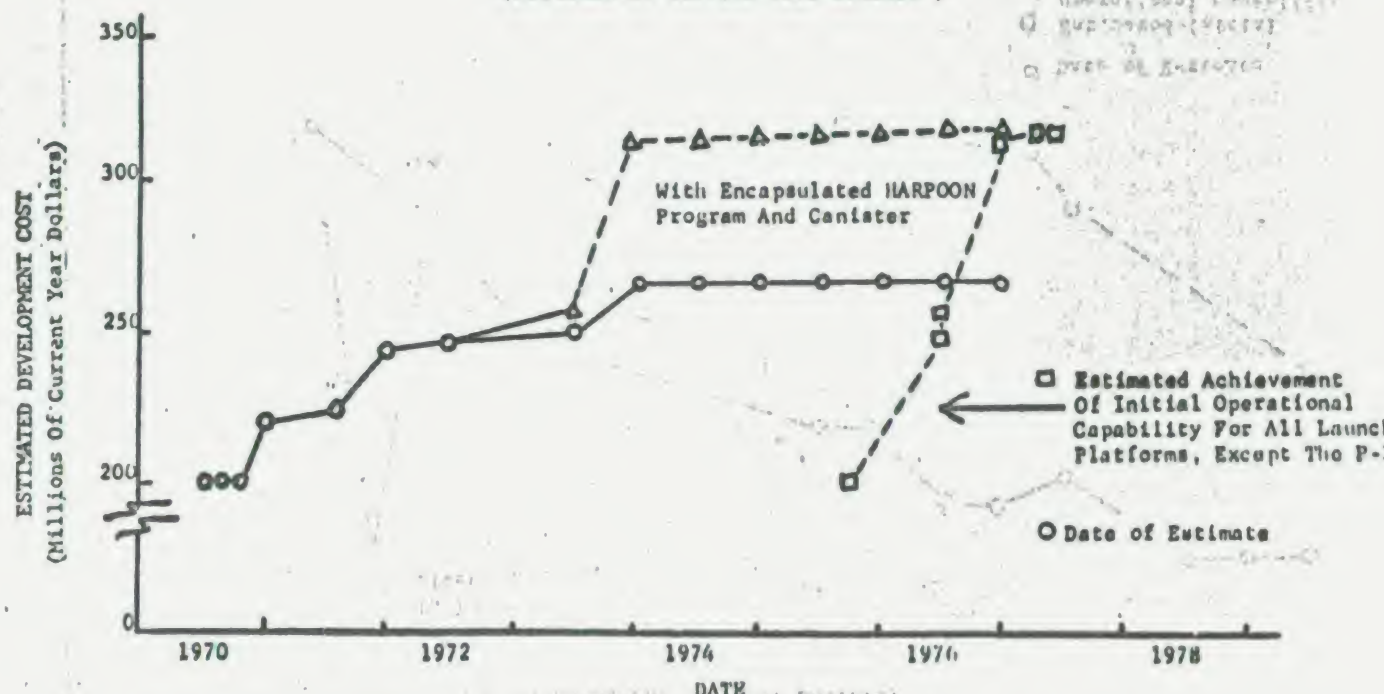


FIGURE 13

HARPOON ESTIMATED DEVELOPMENT COST AND ESTIMATED

DATE OF COMPLETION OF DEVELOPMENT

(Millions of Current Year Dollars)



[1]In interest of simplicity some estimates of initial operational capability achievement are omitted from the graphs.

FIGURE 16

A-10 ESTIMATED DEVELOPMENT COST AND ESTIMATED INITIAL OPERATIONAL CAPABILITY
(Millions Of Current Year Dollars)

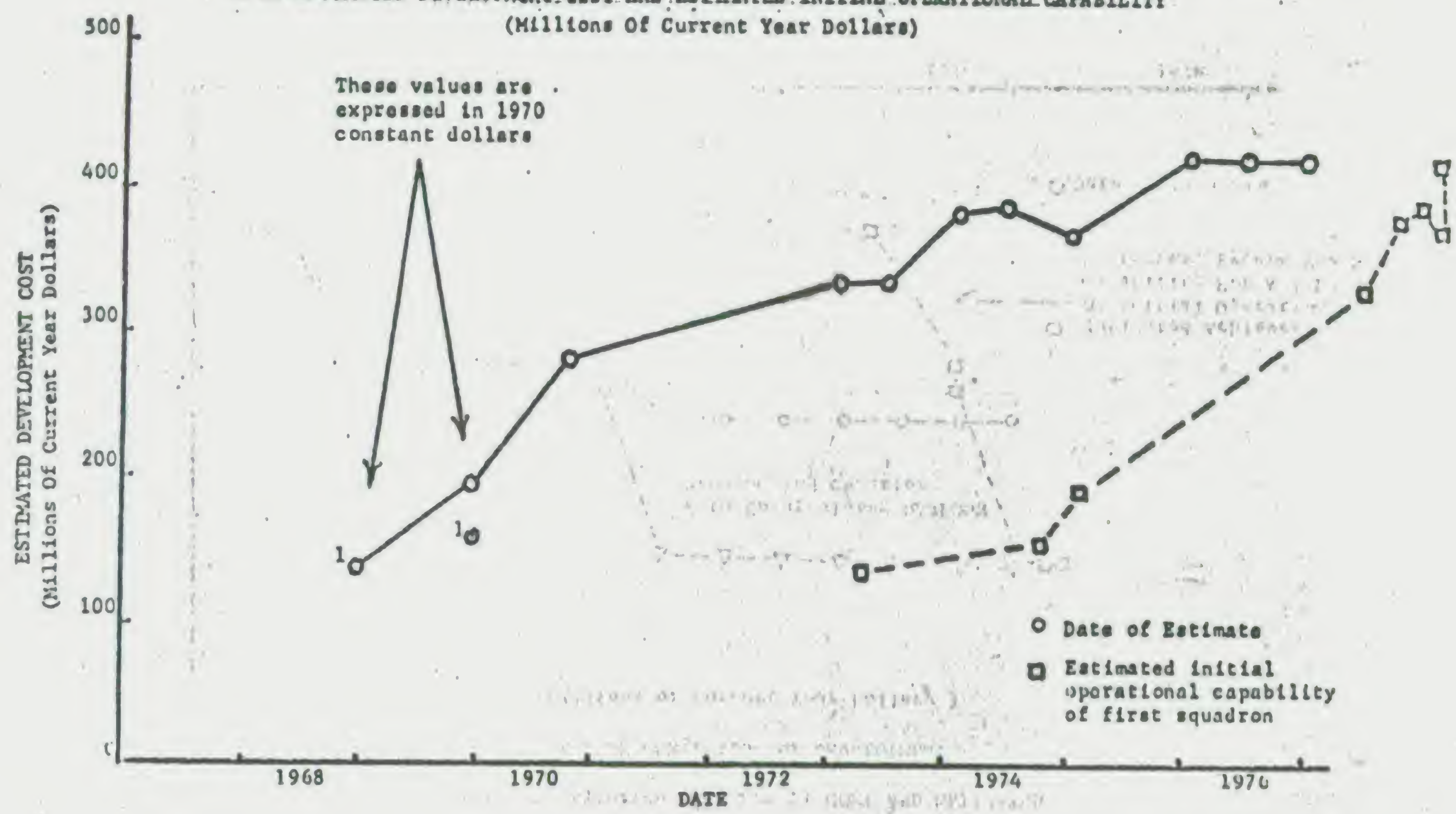


FIGURE 19

E-3A ESTIMATED DEVELOPMENT COST AND ESTIMATED INITIAL OPERATIONAL CAPABILITY
(Millions Of Current Year Dollars)

FIGURE 21

LANDSAT 1 AND 2
ESTIMATED DEVELOPMENT COST AND LAUNCH DATES
(Millions Of Current Year Dollars)

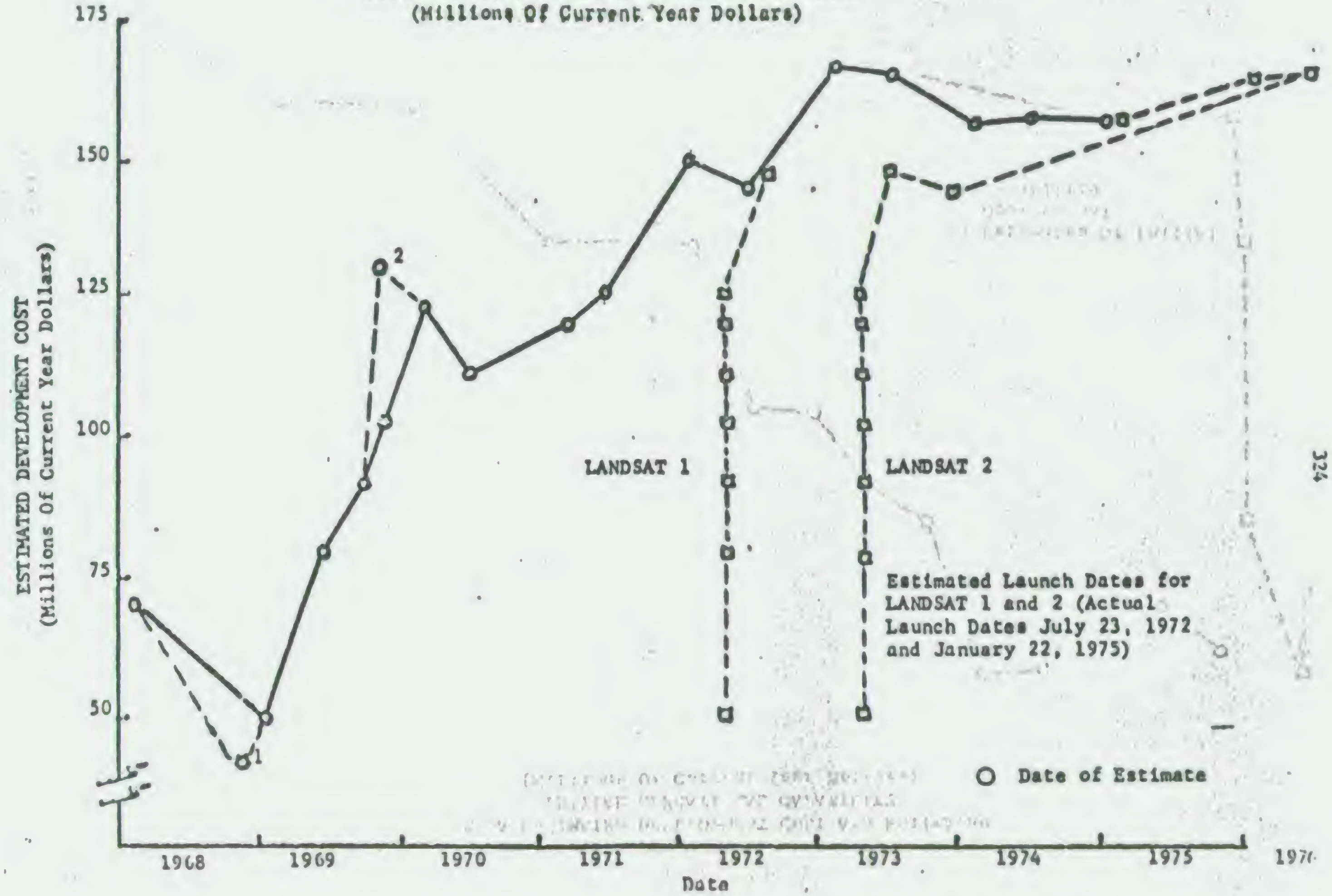
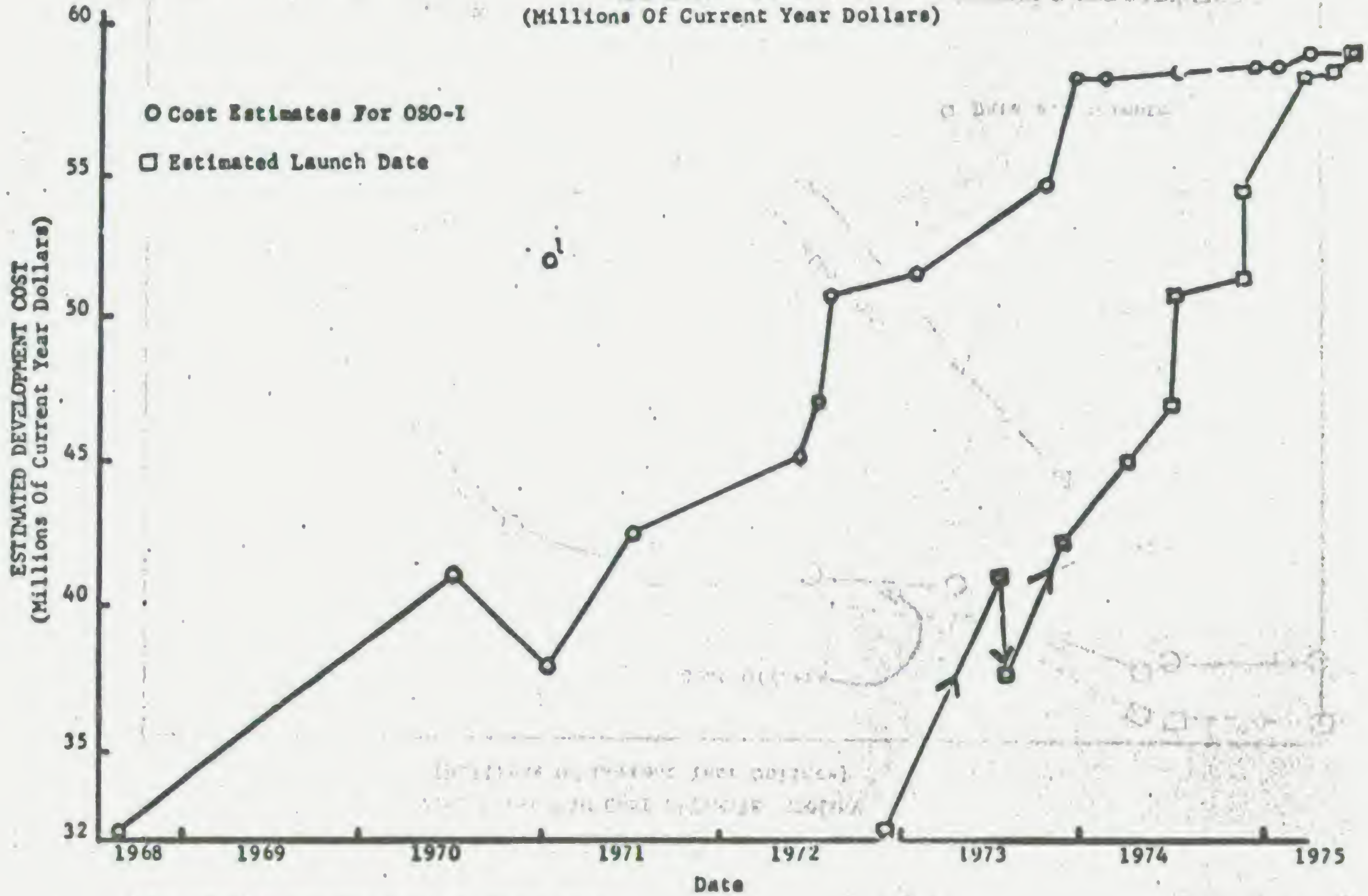


FIGURE 23

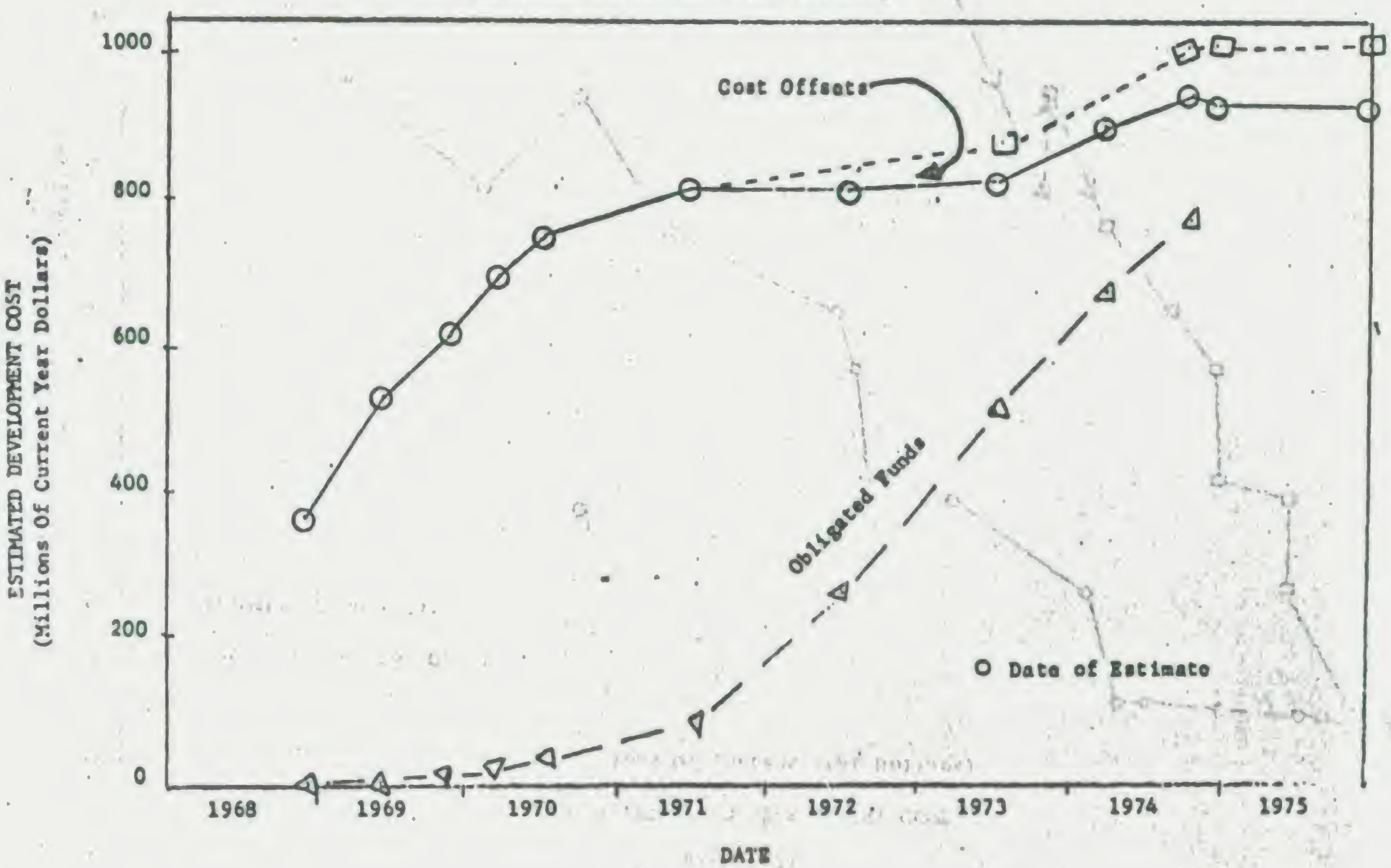
OSO-I ESTIMATED DEVELOPMENT COST
AND LAUNCH DATE
(Millions Of Current Year Dollars)



1 Estimate is contradicted by other data

FIGURE 29

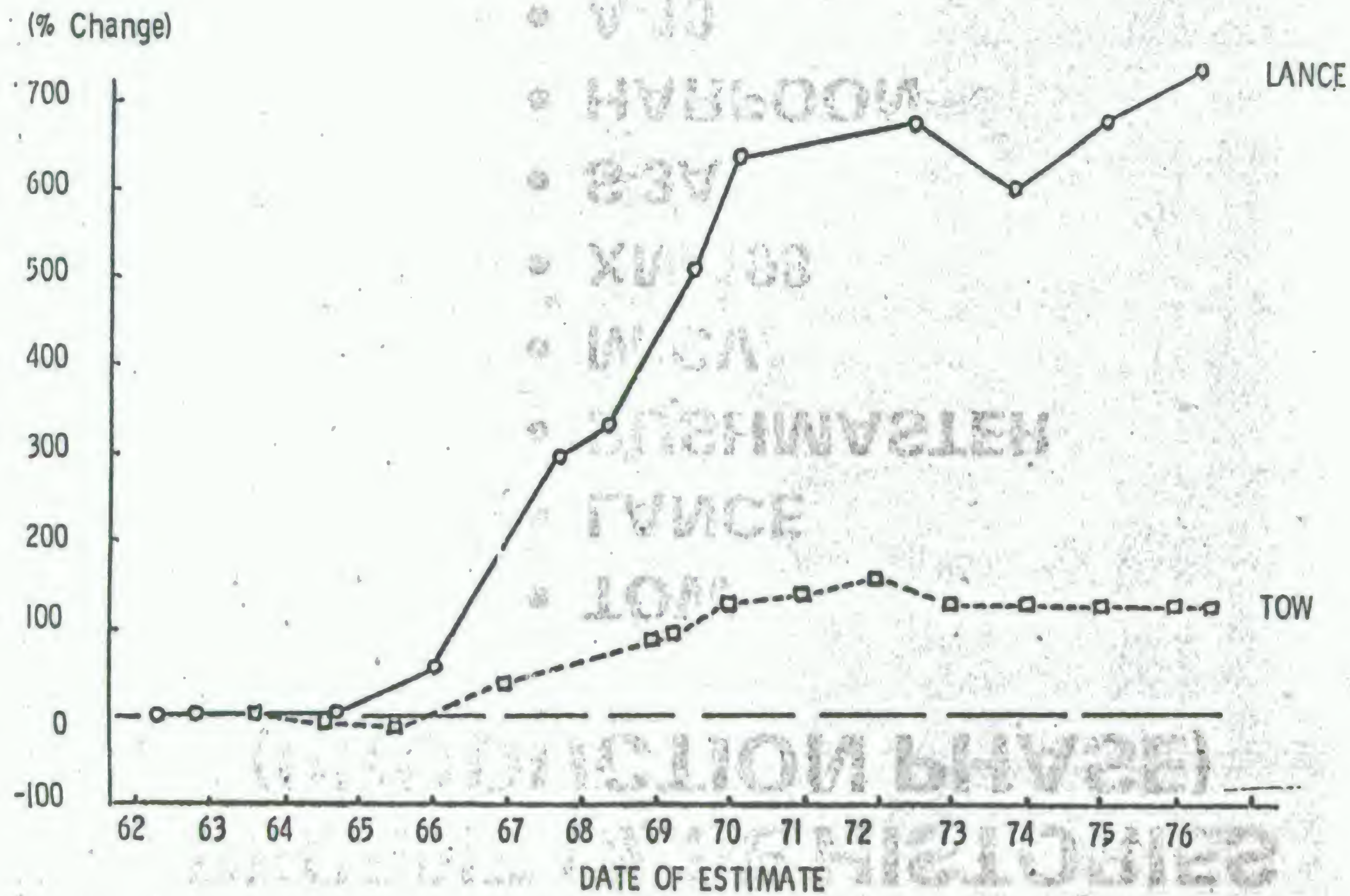
VIKING PROGRAM COST ESTIMATE SUMMARY
(Millions Of Current Year Dollars)

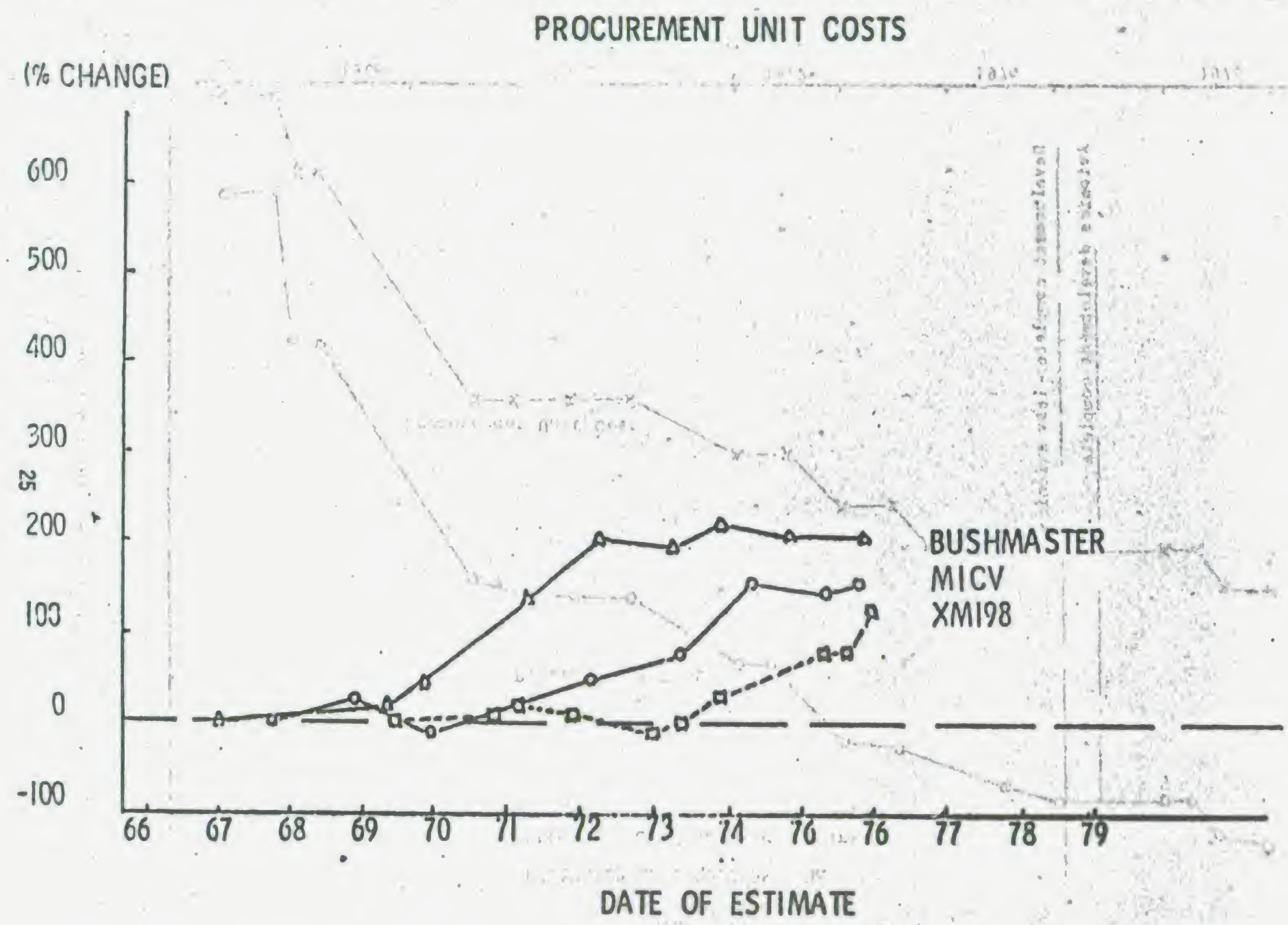


RECENT CASE HISTORIES (PRODUCTION PHASE)

- TOW
- LANCE
- BUSHMASTER
- MICV
- XM-198
- S-3A
- HARPOON
- A-10
- E-3A

PROCUREMENT UNIT COSTS




PROCUREMENT UNIT COSTS
(% CHANGE)
600
500
400
300
200
100
0
-100
66
67
68
69
70
71
72
73
74
76
76
77
78
79
BUSHMASTER
MICV
XM198
DATE OF ESTIMATE

25

FIGURE 12

ESTIMATED UNIT COST OF S-3A

(Millions of Current Year Dollars)

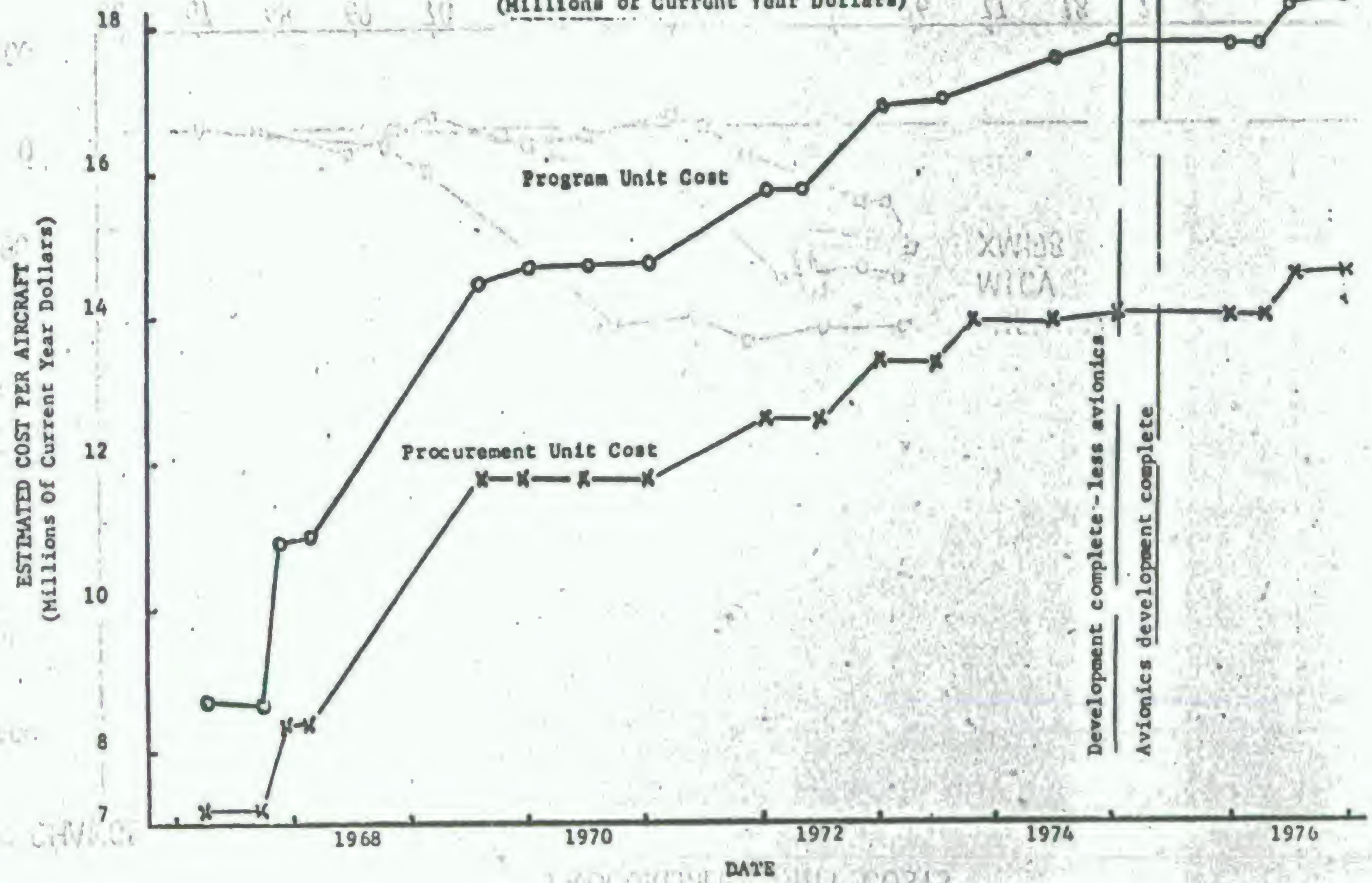


FIGURE 14

HARPOON WEAPON SYSTEM-ESTIMATED PROCUREMENT

UNIT COST

(Thousands Of Current Year Dollars)

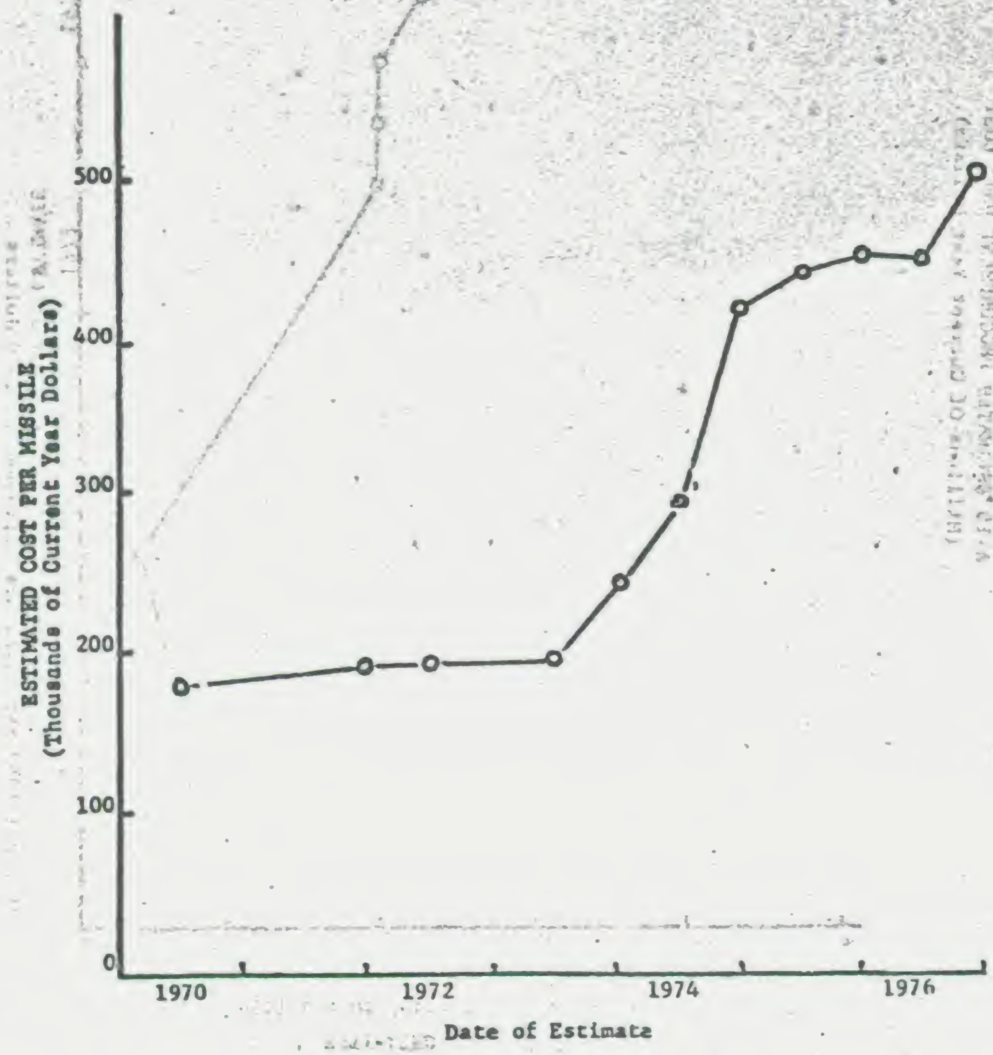
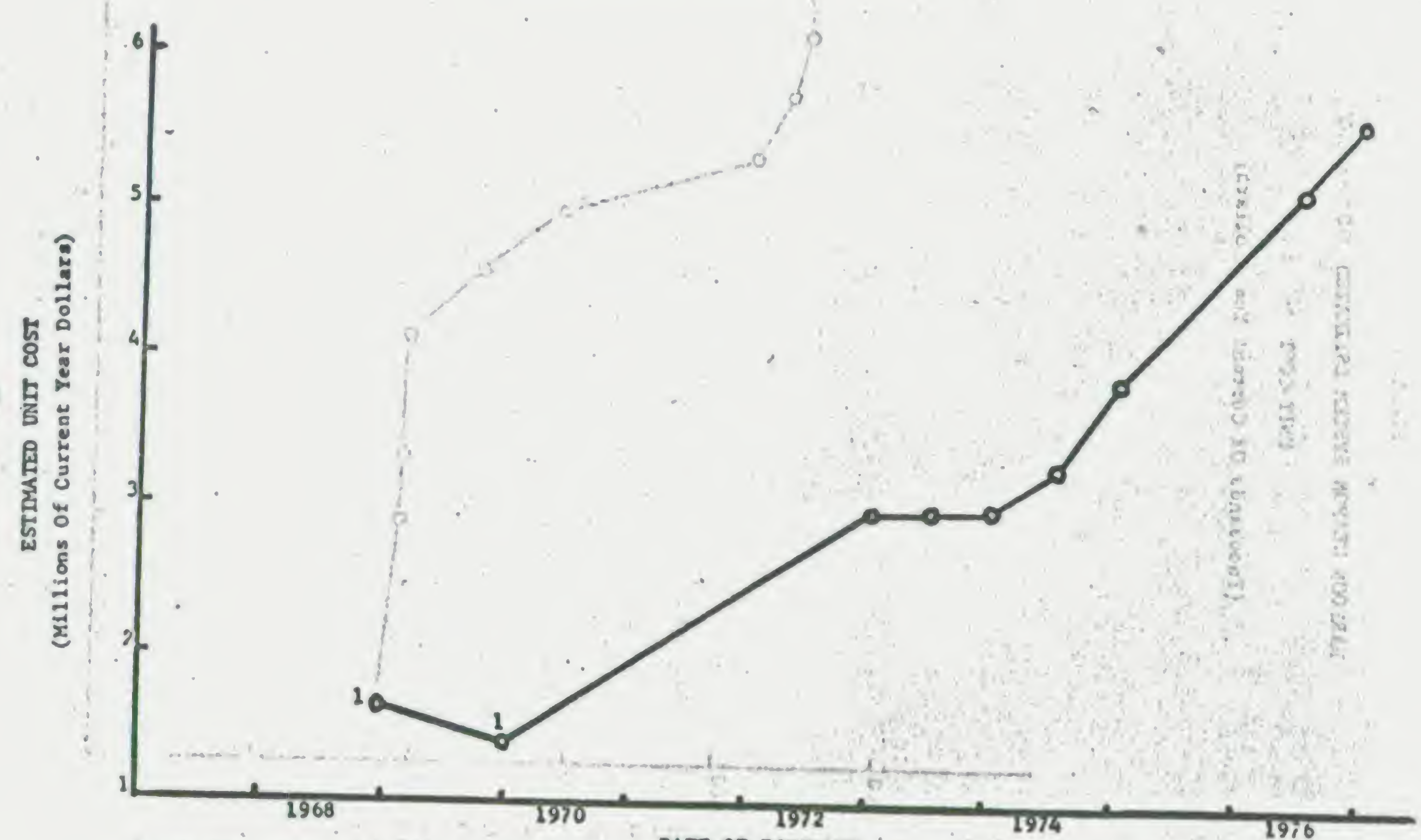


FIGURE 18

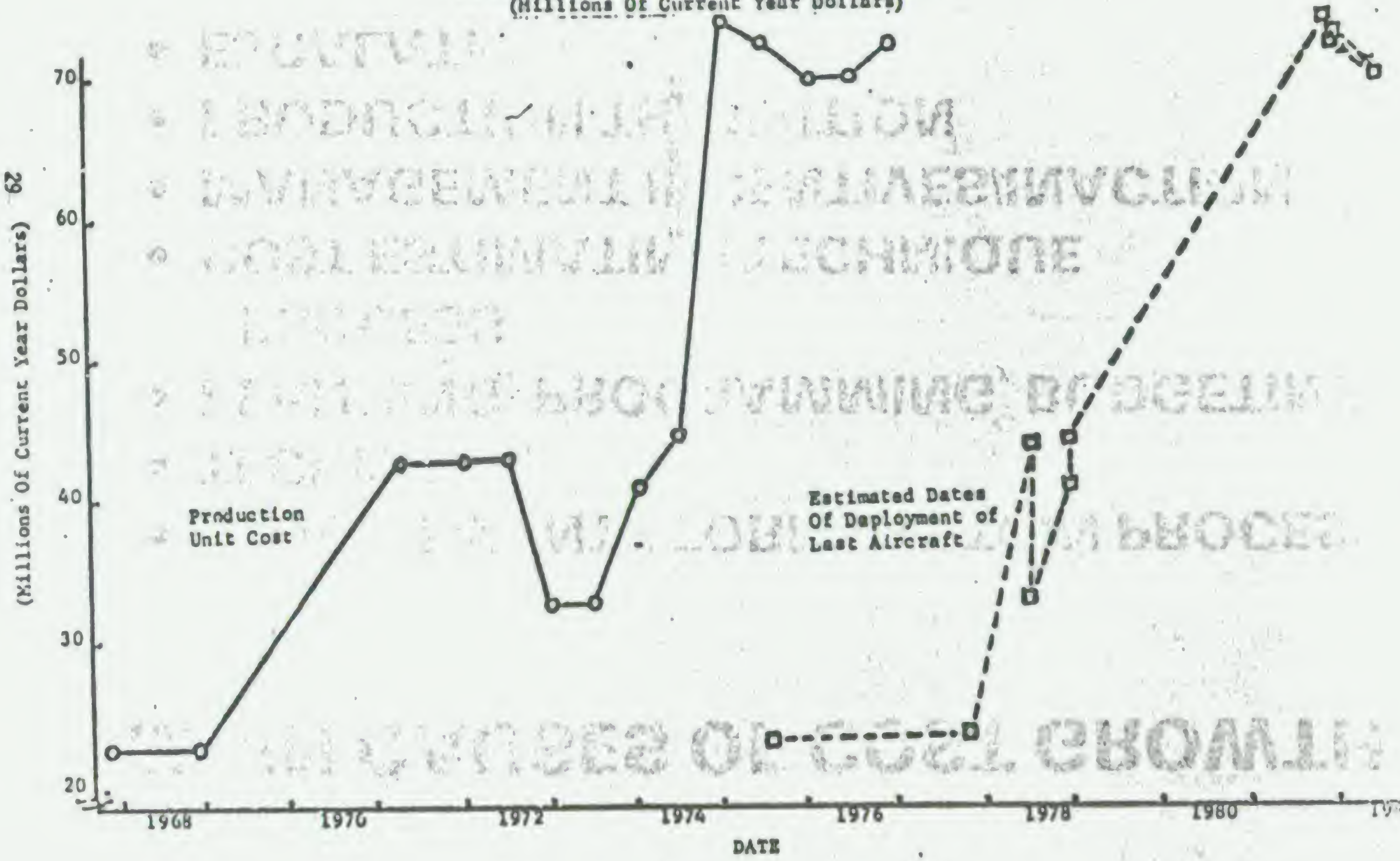
A-10 ESTIMATED PROCUREMENT UNIT COST
(Millions Of Current Year Dollars)



[1]1968 and 1969 estimates are expressed in 1970 dollars

FIGURE 20

E-3A ESTIMATED PRODUCTION UNIT COST AND ESTIMATED DEPLOYMENT DATE OF LAST AIRCRAFT (Millions Of Current Year Dollars)



MAIN CAUSES OF COST GROWTH

- REQUIREMENTS FORMULATION PROCESS
- TECHNICAL
- PLANNING, PROGRAMMING, BUDGETING PROCESS
- COST ESTIMATING TECHNIQUE
- MANAGEMENT INCENTIVES/INACTION
- PRODUCTION TRANSITION
- ESCALATION

MAJOR RESEARCH PROBLEMS

- LONG TIME PERIODS
- BIASED SAMPLE
- INCONSISTENT DEFINITIONS, PROCEDURES, DATA BASE
  - AGENCIES
  - SERVICES
  - SYSTEMS
  - TIME PERIOD
- COST VERSUS PRICE
- CHANGING TECHNOLOGY
- CHANGING MANAGEMENT PRACTICES

TABLE 13

SUMMARY OF COST AND SCHEDULE ESTIMATES
FOR NINE CASE HISTORIES

	First Cost Estimate (Millions of Current Year $'s)	Actual Development Cost (Millions of Current Year $'s)	Development Cost Growth, Percentage	First Estimate of Date of Operational Capability	Actual Date of Deployment	Development Slippage, Months	Development Slippage Factor[1]
TOW	56.4[2]	103.0	+ 83%	Dec. 1965	Sept. 1970	+57 months	2.42
LANCE	132.0	452.6	+243%	Dec. 1967	Jun. 1972	+55 months	1.81
S-3A	437.0	735.5[4]	+ 68%	Oct. 1973	Dec. 1974	+14 months	1.16
HARPOON	204.3	266.8[5]	+ 31%[5]	Sept. 1975	Spring 1977 (est)	+18 months	1.27
A-10	137	422.2	+208%	Mar. 1973	Jan. 1978 (est)	+58 months	1.88
E-3A	580	1467.5	+153%	Nov. 1973	Sept. 1977 (est)	+46 months	1.65
LANDSAT 1 and 2	60[2]	157.0	+162%	Mar. 1972 (1) Mar. 1973 (2)	Jul. 1972 (1) Jan. 1975 (2)	+13 months[3]	1.25
OSO-I	32	59.3	+ 85%	Nov. 1972	Jun. 1975	+31 months	1.60
VIKING	364	923.9	+154%	Fall 1973	Fall 1975	+24 (approx)	1.41
Average			+131%			+35 months	1.61

1 Actual Development Time ÷ Initial Estimate

2 Average of Two Early Estimates

3 Average of LANDSAT 1 and 2

4 Development cost as of December 31, 1976 was $740.4 Million, the added $4.9 Million growth occuring after fleet deployment.

5 Excludes $35.9 Million of development funded with procurement funds, and cannister and capsule program.

TABLE 14

SUMMARY OF FACTORS CAUSING COST GROWTH
FOR NINE DOD AND NASA SYSTEMS

	TOW	LANCE	S-3A	HARPOON	A-10	E-3A	LANDSAT 1 and 2	OSO-I	VIKING
Technically Related Factors	X	M	X	X	X	M	X	X	M
Requirements Related Factors	M	M		X	X	X	-	-	X
Production Related Factors	X	X	X	X	Unknown	X	NA	NA	NA
Management Related Factors	X	M	X		X	X	X		X
Funding Related Factors		X	-			X		M	X
External Factors (Economic Escalation)	X	X	X	X	X	X	X	X	X

M = major factor in causing cost growth
X = factor in causing cost growth
- = probably reduced development costs
Blank = probably not significant
NA = not applicable

TABLE 15

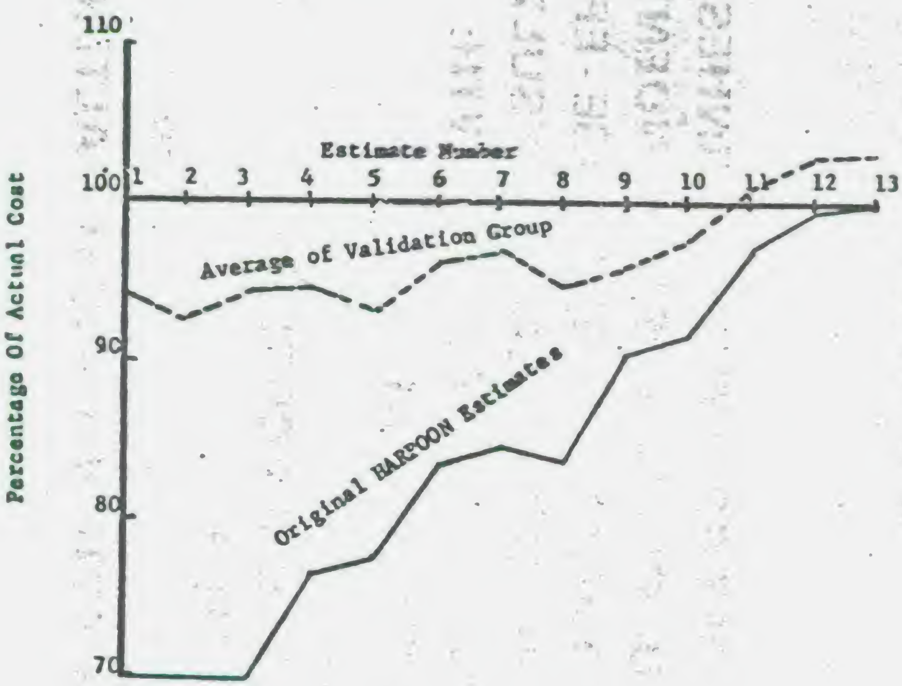
SUMMARY OF PRODUCTION COST AND QUANTITY ESTIMATES FOR SIX DOD SYSTEMS

	Estimated Production Unit Cost At Start Of Development	December 1976 Estimate Of Production Unit Cost	Estimated Production Quantity At Start Of Development	December 1976 Estimate Of Production Quantity[1]
TOW			1,000,000	250,000
LANCE			27,000	
S-3A	$ 7.5 million	$ 14.7 million	260	183
HARPOON	$186,000	$508,000	4,000	2451
A-10	$ 1.62 million	$ 5.63 million	729	733
E-3A	$ 23 million	$ 71.9 million	70	31

[1]The probability of foreign/NATO sales may increase some of these values.

FIGURE 51

COMPARISON OF VALIDATION GROUP ESTIMATES OF HARPOON DEVELOPMENT COST WITH ORIGINAL ESTIMATES



SUMMARY

- LARGE COST GROWTH CONTINUES
- EXTENT OF GROWTH IS DEPENDENT ON DEFINITION
- DETAILED ANALYSIS OF CAUSE - EFFECT IS IMPOSSIBLE
- CONSIDERABLE RESEARCH RESULTS ARE AVAILABLE
- MAIN CAUSES OF COST GROWTH:
  - REQUIREMENTS
  - PPBS
  - TECHNICAL PROBLEMS
  - INCENTIVES
  - ESTIMATING TECHNIQUES
- COST GROWTH VERSUS THE ALTERNATIVE

A COMPARATIVE ANALYSIS OF DOD AND NASA CONTRACT COST OUTCOMES

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INTRODUCTION

Magnitude of Procurement Decisions in the Federal Budget

Projected expenditures of the Federal Government of the United States during the five-year fiscal period from October 1, 1977 through September 30, 1981 total 2,272 billions of dollars.[1] Of this total, purchases by the U. S. Department of Defense average $63.3 billion per year and those by the National Aeronautics and Space Administration average $2.5 billion per year,[2] for a combined total of $66.8 billion, or about 15% of the projected annual Federal outlay.

In terms of Aerospace Vehicles alone, U. S. Government orders amounted to $18.6 billion for 1975, representing 21% of the total Department of Defense and National Aeronautics and Space Administration outlays of $88.6 billion for that year.[3] Contract awards exceeding $10,000 each for Fiscal Year 1975 totaled $36.8 billion for the Department of Defense and $2.0 billion for the National Aeronautics and Space Administration. Of these totals $4.3 billion in Defense[4] and $1.3 billion in NASA[5] were negotiated incentive type contracts with private industry. and $3.8 billion in Defense and $0.3 billion in NASA were negotiated fixed fee contracts with private industry. Thus, of the combined total contracts of $88.6 billion, $5.6 billion, or about 6%, were incentive type contracts and $4.1 billion or about 5%, were cost plus fixed fee contracts.

Given that approximately 11% of the DOD and NASA contracts were of the incentive or fixed fee type, and that these contracts represent about 15% of U. S. Federal Government expenditures, a simple extropolation would indicate that about 1.65%

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[1] Executive Office of the President, The Budget of the United States Government, Fiscal Year 1977, Part 3, Economic Assumptions and Long Range Budget Projections, pp. 35-36. (Washington, D. C.: U. S. Government Printing Office, 1976.)

[2] Ibid.

[3] United States Department of Commerce, Bureau of Economic Analysis, Survey of Current Business, Volume 56, No. 8, pp. S-19 and S-40. (Washington, D. C.: U. S. Government Printing Office, August 1976.)

[4] Office of the Secretary of Defense, Military Prime Contract Awards Fiscal Year 1975, Table 16. (Washington, D. C.. OASD Comptroller, 15 October 1975.)

[5] National Aeronautics and Space Administration Headquarters, Annual Procurement Report, Fiscal Year 1974, p. 17. (Washington, D. C.: NASA Assistant Administrator for Procurement, 1974.)

of projected Federal expenditures of $2.272 billion are candidates for these types of contracts. This represents a forecasted volume as high as $37.5 billion over the next five years for the Department of Defense and NASA alone. Outlays of other Federal agencies in similar procurements would have the effect of increasing this total.

Given the projected magnitude of government procurements which are susceptible to these cost reimbursement type contracts, research and analysis directed toward improvements in the mathematics and micro-economics of the relationships between estimated and actual costs in these contracts can have significant impacts on the efficacy of governmental purchasing activities in the future. This paper is an empirical comparative analysis of such cost outcomes based on a random sample of 174 NASA and 300 Army contracts completed during the period 1964 to 1975.

The Market Mechanism

As noted by Peck and Scherer[6] in 1962, reiterated by the Commission of Government Procurement[7] in 1972 and by Fox[8] in 1974, the market system in which the government operates differs from the private industrial market in several crucial ways.

First, the market is determined weakly, if at all, by supply and demand. Rather, Congress determines annually how much will be spent by the government on research, development and production of major systems. These determinations are based not so much on what may be offered in the market place, but, rather, by political and economic conditions, international events and the interests of the Congressmen and Senators who serve on defense, space, budget, appropriation and other committees and subcommittees.

Secondly, the prices of these procurements are not usually determined by normal market competition. Cost-reimbursement and incentive contract prices depend ultimately on costs actually experienced. The contractor's profit is initially determined by the level of costs estimated when the contract is negotiated, and is subsequently renegotiated each time a contract change affecting price occurs. Such changes occur frequently, especially in the typically large incentive and cost-reimbursement contracts calling for advances in the technological state of the art.

Thirdly, because the government is usually the only buyer and investment barriers to entry limit the number of suppliers, the market is frequently referred to as a "bilateral monopoly" in that the buyer and seller exist interdependently; neither can achieve its principal objectives without the other.

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[6] Peck, Merton J. and Scherer, Frederic M., The Weapons Acquisition Process: An Economic Analysis. (Cambridge, Mass.: Harvard University Press, 1962.)

[7] McGuire, E. Perkins, Chairman, Report of the Commission on Government Procurement. (Washington, D. C.: U. S. Government Printing Office, 1972.)

[8] Fox, J. Ronald, Arming America, How the U. S. Buys Weapons. (Boston, Mass.: Harvard University Press, 1974.)

These differences, more specifically characterized for the defense and aerospace market in Table I-1, are particularly acute in the types of procurement which are most susceptible to cost reimbursement contracting in fields as diverse as atomic energy development, scientific research, aerospace technology, weapons systems development, environmental improvement, transportation, and health protection. An increasing number of such procurements consist of major military or civilian systems of vital importance to the nation's technological advancement and future well-being. If for no reason other than the fact that the government usually is the only customer for such systems and the number of suppliers is limited, the normal rules of the private sector market do not apply. The rules are unique even for the hundreds of thousands of commercially available, off-the-shelf items repetitively procured by the Government, being bound as they are by procedural requirements specified in law and the administrative bureaucracy. Tables I-2 and I-3 indicate FY 1976 awards by competition and statutory authority for DOD and NASA respectively.

TABLE I.1. SUMMARY OF DIFFERENCES IN CHARACTERISTICS BETWEEN THE PRIVATE AND PUBLIC INDUSTRIAL MARKET

Market Characteristics[9]

Private Market	Public Market
The seller initiates new product innovations based on analyses of potential markets. He has no certain knowledge of a product's saleability.	The buyer establishes the requirements for a product. The producer then begins development and production.
The buyer has a wide range of choice between products in the same category that have real or advertised differences.	Relatively few products are produced simultaneously for the same mission. Although the buyer sometimes has the option to choose among prototypes, the time and cost of producing new systems once production has begun discourages replacement.
Price is a dominant factor in a buyer's choice because adequate substitutes for a product are often available.	Price is only one of the factors that govern a customer's choice. It may be far less important than quality, availability, or techeology.
The market tends to be impersonal. Buyers and sellers act independently.	The market is highly personal. The buyer has constant contact with the seller's organization.
The producer finances the development-production effort.	The buyer bears most of the development cost and may provide equipment and facilities for the use of the producer.
The market usually contains several, or many, customers for each product.	The market is essentially one-customer (monopsonistic).
Prices are primarily determined by competition.	Price is determined by an evaluation of anticipated and actual costs.
Demand is either relatively constant (e.g., for staples), or tends to be a function of disposable income (e.g., for non-essentials).	Demand is a function of the technology available, or of estimates of a potential enemy's technological resources.
The basic design of the product changes slowly and requirements for a given model are relatively stable.	The product may be technologically obsolete before production is completed.

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9 Adapted from Cleland, David I. and King, William R., "The Defense Market System," Defense Industry Bulletin, January 1968.

TABLE I-2. DEPARTMENT OF DEFENSE

AWARDS BY COMPETITION & STATUTORY AUTHORITY,

FISCAL YEAR 1976

(Summarized from "Military Prime Contract Awards Fiscal Year 1976", Office of the Secretary of Defense (Comptroller), Washington D.C.)

	AMOUNT (Billions)	PERCENT
TOTAL	$40.8	100.0%
Competitive Subtotal	17.4	42.6
Formally Advertised	3.2	7.9
Negotiated	14.2	34.7
Non-Competitive Subtotal	23.4	57.4
Follow-on After Competition	5.8	14.3
Sole-Source	17.6	43.1

Negotiation Authority: (14.2 + 23.4 = $37.6) = (92.1% = 34.7 + 57.4)

		AMOUNT	PERCENT
(1)	National Emergency	2.2	5.9
(2)	Public Exigency	2.2	5.9
(3)	Not exceeding $10,000 each	2.5	6.6
(4)	Personal/Prof. Services	0.1	0.3
(5)	Educational Institutions	0.5	1.3
(6)	Outside of U.S.	2.0	5.3
(7)	Medical Supplies & Medicines	0.1	0.3
(8)	Supplies for Resale	0.5	1.3
(9)	Subsistence Items	1.7	4.5
(10)	Competition Impractical	13.2	35.1
(11)	Experimental, Research, Development	5.8	15.4
(12)	Classified Purchases	0.1	0.3
(13)	Standardization of Parts	0.1	0.3
(14)	High Initial Investment	4.4	11.7
(15)	Negotiated after F.A.	0.0	0.0
(16)	Mobilization Base	1.9	5.0
(17)	Other Authorized	0.3	0.8

AWARDS BY MAJOR "HARD GOODS" - FY76 (Work in U.S.)

	AMOUNT	PERCENT
Aircraft	$ 7.0	23.8
Missiles & Space	4.7	16.0
Electronic, Communication	4.5	15.3
Ships	3.8	12.9
Services (to Hard Goods)	3.2	10.9
Construction	2.2	7.5
Misc. Hard Goods	1.3	4.4
Tank, Automotive	1.3	4.4
Ammunition	0.9	3.1
Weapons	0.5	1.7
TOTAL	$29.4	100.0%

TABLE I-3. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AWARDS BY COMPETION AND STATUTORY AUTHORITY,
FISCAL YEAR 1976

(Summarized from "NASA Annual Procurement Program Fiscal Year 1976, NASA Headquarters", (Code HA) Washington, C. C. 20546)

	AMOUNT (Billions)	PERCENT
TOTAL	$ 2.6	100.0%
Competitive Subtotal	1.9	73
Formally Advertised	0.4	15
Negotiated	1.5	58
Non-Competitive Subtotal	0.7	27

Negotiation Authority: (1.5 + 0.7 = $2.2) = (85% = 58 + 27)

		AMOUNT	PERCENT
(1)	National Emergency	0.04	1.8
(2)	Public Exigency	*	*
(3)	Not exceeding $10,000 each	0.04	1.8
(4)	Personal/Prof. Services	0.01	0.5
(5)	Educational Institutions	0.26	11.8
(6)	Outside of U.S.	0.03	1.4
(7)	Medical Supplies & Medicines	*	*
(9)	Subsistence Items	*	*
(10)	Competition Impractical	0.79	35.9
(11)	Experimental, Research, Development	0.95	43.2
(17)	Other Authorized	0.08	3.6

* Less than 0.5%

AWARDS BY PROGRAM OFFICE - FY76 (Work in U.S.)

	AMOUNT (Billions)	PERCENT
Space Flight	$ 1.6	61.5
Space Science	0.3	11.5
Applications	0.2	7.7
Aeronautics	0.2	7.7
Tracking & Data Acquisition	0.1	3.8
Energy Programs	0.01	0.1
Non-Program (services)	0.2	7.7
TOTAL	$ 2.61	100.0%

The Economics of Government Contracting

The first comprehensive treatment of economic incentives to be reviewed is that by Peck and Scherer.[10] This 1962 volume presents an overall economic analysis of the weapons acquisition process in the Department of Defense, drawing on a series of case studies involving seven advanced commercial products used for comparison with twelve advanced weapons - aircraft and missiles - covering the period 1920 through 1959. A principal conclusion, based on regressions of expert opinion on empirical data, is that "reasonably consistent ordinal measurement of overall weapon system development program performance by knowledgeable persons is feasible." Although not necessarily startling, this conclusion tends to support the thesis that empirical or objective, as opposed to subjective, research is feasible and neither counter-intuitive nor anti-judgmental. The comprehensive work by Peck and Scherer, among other recommendations, made a very specific proposal concerning the data base for procurement research: they strongly recommended the development of a well structured data gathering and analysis organization at the Secretary of Defense level to provide the basis for improved contracting decisions.

The Statistical Distribution of the Ratio of Actual to Estimated Costs

In 1967 Moore,[11] in writing specifically on incentive contracting, drew a number of inferences concerning cost growth. The remarkable aspect of his analysis for the purpose of this research is his treatment of the sample distribution of variation in actual costs as compared to estimated costs. His data are presented as follows:

	Cost Overrun or Underrun (%)	Number of Contracts	Percent
1.	Underrun		
	Over 20	10	4.4
	10 - 19	43	18.9
	5 - 9	64	28.1
	0 - 4	51	22.4
	Subtotal	168	73.4
2.	Overrun		
	0 - 4	31	13.6
	5 - 9	12	5.3
	10 - 19	8	3.5
	Over 20	9	3.9
	Subtotal	60	26.6
	TOTAL	228	100.0

[10] Peck, Morton J. and Scherer, Frederic M., The Weapons Acquisition Process: An Economic Analysis. (Cambridge, Mass.: Harvard University Press, 1962.)

[11] Enke, Stephen, Ed., Defense Management, Chapter 12, Moore, F. T., "Incentive Contracts." (Englewood Cliffs, N. J.: Prentice Hall, Inc., 1967.)

Although Moore assumed normality for this distribution, it is quite clearly skewed to the overrun values. The mean is -3.5% whereas the mode is -7%, using the midpoints of the closed class intervals and ± 25% for the open end intervals.

The most recent comprehensive treatment of government contract cost outcomes to be reviewed is that by Cummins[12] published in 1973. His data base consisted of 118 Army contracts completed between 1965 and 1970 which parallels the Army data base used in this analysis. All of his contracts had a final cost of at least one million dollars. His bilateral bargaining model was essentially an extension of a doctoral dissertation by Berhold[13] with relaxation of the assumption that the contract would be finalized at the minimum acceptance level for the contractor. Rather, the aspect of relative bargaining strengths of the parties is introduced as an exogenous variable, and the cost outcomes are treated as endogenous variables. He tests his model in both the fixed price incentive and cost plus incentive fee contract forms. His assumptions include the propositions that (1) defense goods are "normal" goods in the profit and organizational view of the contractor, (2) the expected cost to the government of a given contract is a function of relative bargaining strengths of the parties, (3) both parties have perfect knowledge of each other's utility functions, and (4) all decisions are made at the time the contract is initially negotiated. The empirical results support the proposition that cost overruns are primarily influenced by the contractor's relative bargaining strength. His final conclusions all relate to extracontractual incentives: that cost overruns are a function of the contractor's degree of risk aversion, his extent of "moral hazard" and his relative bargaining strength. As in all the literature reviewed, the subject of non-normality of the distribution of contract outcomes is not addressed.

Summary of the Existing Literature

The existing literature on government contracting is extensive in its treatment of extracontractual incentives such as company growth, prestige, follow-on business, the availability of open capacity, utility functions, risk perceptions, cost estimating bias, and bargaining strength. With respect to endogenous contractual incentives, and particularly with respect to the analytical treatment of empirical research, the literature seems rather meager. The literature does, however, include a number of models intended to describe contract cost outcomes as well as some discussion of the statistical distribution of these outcomes. As noted in this brief review, this existing literature is either silent on or assumes that the ratio of final to adjusted negotiated cost is normally distributed.

The research reported herein departs from the literature by testing the hypothesis that the ratio of final to adjusted negotiated cost in the contracts included in the sample is normally distributed.

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[12] Cummins, John M., Cost Overruns in Defense Procurement. (Evanston, Ill.: Northwestern University, Ph.D. dissertation, 1973.)

[13] Berhold, Marvin, An Analysis of Contractual Incentives. (Los Angeles, CA.: University of California, Ph.D. dissertation, 1967.)

Further, statistical analyses are performed on a sample of 174 NASA and 300 Army contracts to compare contract type and cost outcomes as related to a number of procurement situational variables. In addition to standard descriptive statistics, situational variables such as procurement type, commodity, contractor and amount and date of contract are regressed on contract type for the entire sample. In addition, the sample is stratified by contract type and regressions are performed on the ratio of final to negotiated cost as a function of number of contract modifications, procurement authority, negotiation authority, commodity, and amount of initial contract. Correlation matrices among these variables also are reported.

EMPIRICAL RESULTS

Description of the Data

The empirical data for the Army contracts included in this study were provided by the U. S. Army Procurement Research Office. The data are drawn from a random sample of 300 contracts, each in excess of $500,000, completed between 1964 and 1971. Collection of this data base required 15 man months of effort, and was used as the basis for a report on contract cost growth in major Army programs.[14] The findings and recommendations of the report included the observations that procurement of additional work amounted to 58% of the total sample cost growth, that engineering changes almost always increased the contract price, and that although under-runs occurred more frequently than over-runs, the total amount of over-runs far exceeded that for under-runs.

The total final cost of all 300 Army contracts represented in the sample is in excess of two billion dollars. The total includes 112 Firm Fixed Price (FFP), 53 Fixed Price Incentive (FPI), 50 Cost Plus Incentive Fee (CPIF), 82 Cost Plus Fixed Fee (CPFF), and 3 Cost Plus Award Fee Contracts.

The empirical data for the NASA contracts included in the total sample were obtained from two sources. A sample of 150 contracts was obtained from the Ames Research Center (ARC); the balance of 24 large cost reimbursable contracts was obtained from NASA Headquarters. The ARC sample consists of 85 fixed price and 65 cost reimbursement type contracts. All 24 of the NASA Headquarters sample were of the cost reimbursement type, including 6 CPFF, 5 CPIF, and 13 CPAF contracts. Unlike the Army data, the NASA data base is not complete with respect to contract type, contractor identification, commodity, negotiation authority, nor procurement type (Research, Development, Production, Services, or Study). As a result the regression analyses are more limited for the NASA contracts. In addition, the aggregate analyses by contract type are limited for the NASA contracts to fixed-price (FP) or cost reimbursement (CR) categories whereas separate analyses were possible for the Army contracts for FFP, FPI, CPIF and CPFF.

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Launer, Robert L., Candy, Harold F., and Carter, Shirley H., Contract Cost Growth in Major Army Programs. (Fort Lee, VA: U. S. Army Procurement Research Office, May 1973.)

DESCRIPTIVE STATISTICS

Tables III-1 through III-6 summarize the results of the standard descriptive statistics calculated from the data available. (Note that these tables and all analytical tables to follow are included in a technical appendix. This appendix is not included in this paper because of space limitations. Interested readers may write to the authors for a copy of the technical appendix.)

Means, standard deviations, and measures of skewness and kurtosis are reported for all 474 contracts in the sample, as well as on a comparative basis by Agency (Army, NASA) and by contract category (FP, CR). In addition. Tables III-7 and III-8 summarize the data for Army contracts only, by contract type.

Table III-1 displays the basic descriptive statistics for the total sample and as stratified by agency and contract category for the initially negotiated contract amounts. It is noted that the arithmetic mean or average value for all 474 contracts is \$3.0 million with a standard deviation of \$8.7 million for a coefficient of deviation of 2.9. The 24 NASA contracts have by far the highest mean initially negotiated values with the 150 NASA contracts at the extreme low end of the mean values. An unexpected result may be that the fixed price category has a higher mean value than the cost reimbursement category. As in all the dollar cost statistics as opposed to cost ratio statistics, all distributions are asymmetrical and skewed to the higher values. The kurtosis values indicate that all categories are leptokurtic or highly peaked at central or modal amounts, all being considerably in excess of 3.

Table III-2 indicates that the large NASA Headquarters contracts resulted in very high dollar values of modifications subsequent to initial negotiation: a mean of \$55.8 million in modifications related to a mean of \$57.5 million in initial negotiation for a 97% modification increase, whereas the combined Army sample exhibited a 2.4/4.7 or a 51% average increase. Again, all values are highly peaked and skewed to the right.

Table III-3 displays the adjusted initial amounts; that is, the initial contract amounts plus the subsequent contract modification amounts. Table III-4 then shows the final contract amounts, including overruns/underruns and modification amounts. The mean for all 474 contracts has grown from \$3.0 million initially to \$4.6 million for a 53% total average cost growth. The Army total average cost growth is 53% compared to 111% for the total NASA cost growth.

It may be more instructive, or at least easier to evaluate, if we examine ratios rather than absolute amounts. Tables III-5 and III-6 display these results, both uncorrected for modifications occurring subsequent to the initial contract and after correction for the dollar value of modifications, respectively. The highest ratio cost growth again occurs in the 24 large NASA contracts, both corrected (17.2%) and uncorrected (140.9%). The lowest growth, as expected, is in the fixed price category showing a 47% uncorrected growth and none after correction. The NASA-ARC contracts show a slight reduction in cost ratio of -0.7% after correction. The growth in the cost-reimbursement contracts is 101.9% uncorrected, but only 2% after adjustment for modifications. The Army-NASA comparisons show nearly equal cost growth ratios: Army 72.5% uncorrected to 0.5% corrected and NASA 73.8% uncorrected to 1.7% corrected. With respect to symmetry of the cost ratio distributions, all but the fixed price category are skewed to the higher values, indicating that the mean or expected ratio is

righer than the modal or most likely value. All ratio values are peaked, with kurtosis values in excess of 3. In measures of dispersion, the NASA contracts show higher standard deviations than the Army contracts.

Referring to the Army comparative analyses by contract type, Tables III-7 and III-8, it is noted that the 53 FPI contracts have the largest average value and variation in amounts initially negotiated, but that the 50 CPIF contracts dominate all other contract types once contract modifications are taken into account. With reference to symmetry of the distributions, all values are skewed to the right, with the CPIF contracts in every case having the largest shift of the mean or average values to the right of the modal or most likely (negotiated) value. As to peakedness, all kurtosis values exceed 3 indicating leptokurtic or highly peaked distributions. Again, the CPIF contracts dominate in this characteristic.

In Table III-8, in which the ratios rather than absolute amounts of overrun and underrun are displayed, it is noted that although the non-incentive contract types have the largest mean percentage cost overruns before adjustment for contract modifications, the CPIF is the only contract type exhibiting an average overrun ratio after correction for modifications. Further, the FPI is slightly skewed to the left (mean less than modal value) and is more peaked than the CPIF.

Regressions and Correlations

In order to gain additional insight with respect to strength of association among variables in the data base, several step-wise multiple linear regressions were run on the data. Dependent variables chosen were contract type and ratio of final to negotiated cost by contract type. Since the Army data are more complete with respect to attributes or situational variables, these regressions are discussed first, to be followed by a less comprehensive set of regressions on the comparative Army-NASA data.

The first Army analysis regressed the contractor code, commodity code, negotiation authority, date of contract, amount of initial contract and procurement type as independent variables on contract type as the dependent variable. The procurement type (Research and Development, Production, Services, or Study) entered first with a coefficient of determination (R^2) of 11.6% at the 100% significance level. Steps 2, 3 and 4 brought in the date of contract (7.15% added R^2), the commodity (2.4% added R^2), and the contractor (0.5% added R^2), respectively, for a total of 19.6% variation explained in 4 steps. Maximum positive correlation of +0.34 occurred between the contract type and procurement type, as noted in the regression. Maximum negative correlation of -0.29 occurred between the contract type and date, also as shown in the regression. In addition, a negative correlation of -0.28 was noted between the commodity and the amount of the contract, both independent variables in this regression. Virtually no correlation was shown between the negotiation authority and the amount of the contract. The output of this regression is summarized in Table III-9.

The regressions for FPI contracts, using the overrun/underrun ratios as the dependent variables, resulted in only 4% of the variation in the ratio of final to adjusted initial contract amount being explained by procurement type, the only entering variable. Using the ratio of final to unadjusted initial amount as the dependent variable, 13.4% of the variation was accounted for by procurement type in Step 1, with an additional 9.2% explained by the commodity in

Step 2 for a total R^2 of 22.6%. The correlation matrix showed a maximum correlation of +0.59 between the initial contract amount and the number of modifications, a negative correlation of -0.50 between the commodity and initial contract amount, and virtually no correlation between the contractor and the negotiation authority. These results are summarized in Table III-10.

The regressions for CPIF contracts, again using the overrun/underrun ratios as the dependent variables, resulted in 17.25% of the variation in the ratio of final to adjusted cost explained by the negotiation authority. Using the ratio of final to initial cost as the dependent variable, 47.52% of the variation was associated with the number of modifications. In the correlations of independent variables, a +.9097 correlation coefficient was found between number of modifications and initial contract amount. Apparently then, for CPIF contracts particularly, the number of contract modifications is strongly associated with both overruns and the total size of the contract. Although it is dangerous to infer cause and effect relationships from regression results, it appears that large contracts with many modifications tend to lead to large cost overruns. The results of the CPIF regressions and correlations are shown in Table III-11.

Since incentive and cost-reimbursement contracts are of principal interest, Table III-12 summarizes the regression results for the Army FPI, CPIF and CPFF contract types. Results of the regressions for the combined sample of 300 Army and 174 NASA contracts as well as for the NASA contracts alone are shown in Tables III-13 through III-17. Because none of the independent variable values are known prior to negotiation these regressions are not nearly as meaningful as the Army contract regressions which included "a priori" situational variables such as the commodity, negotiation authority and procurement type. These situational variables were not available in the NASA data base as collected.

Distributions of Cost Ratios

As indicated in the foregoing review, the literature is either silent on or assumes that the ratio of final to adjusted negotiated cost is normally distributed. The test of the hypothesis that this ratio is appropriately represented by a Normal Distribution resulted in rejection at the .05 level of significance for all categories except for the small NASA Headquarters sample.

The goodness of fit test used was the Kolmogorov-Smirnov one-sample test described by Clark and Schkade.[15] A principal advantage of this test is that it may be used on small samples when the chi-square test would be impractical because of the requirement that each expected frequency be at least five. The test compares the sample cumulative distribution with the theoretical distribution. The point at which these two distributions show the greatest divergence is measured and compared against critical values at various levels

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15 Clark, Charles T. and Schkade, Lawrence L., Statistical Methods for Business Decisions, page 436. (Cincinnati, Ohio: Southwestern Publishing Company, 1969.)

of significance. For sample sizes larger than 35, the critical value of this maximum difference at the .05 level of significance is $1.36/\sqrt{n}$, where n is the sample size. The test at the .05 level of significance results in rejection of the hypothesis that the sample is drawn from a Normal distribution. These results are shown in Table III-6.

SUMMARY AND IMPLICATIONS

The preceding discussion is concerned with the relationship between negotiated and actual costs in government procurement. The research focuses on a descriptive evaluation of cost outcomes for 474 contracts from two governmental agencies as well as an inferential analysis of cost outcomes against a number of situational variables. The results indicate that there are no striking differences between Army and NASA contract cost outcomes, that cost ratios are not normally distributed as implied in the literature, and that somewhat counter-intuitive relationships between situational variables and both contract type as well as cost ratios prevailed. The contention in this discussion is that this paper makes a contribution because it provides inter-agency comparisons, examines a broad set of variables selected from a random sample of contracts, and focuses on the general behavior of costs from an objective, descriptive, statistical point of view. Finally, the research is anchored in actual cost behavior rather than the opinion statement, untested theory, or "horrible example" analysis which has come to represent much of what procurement research is today.

A GENERAL TECHNIQUE FOR R&D COST FORECASTING

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INTRODUCTION

During the 1920's, two statisticians, Raymond Pearl and L.J. Reed, were extensively involved in research dealing with forecasting rates of population and biological growth. They discovered that the S-shaped curve form of Figure 1 accurately represented growth of this type which is characterized by three distinct phases: (1) a slow period of development, (2) a rapid period of expansion, and (3) a tapering off at maturity.

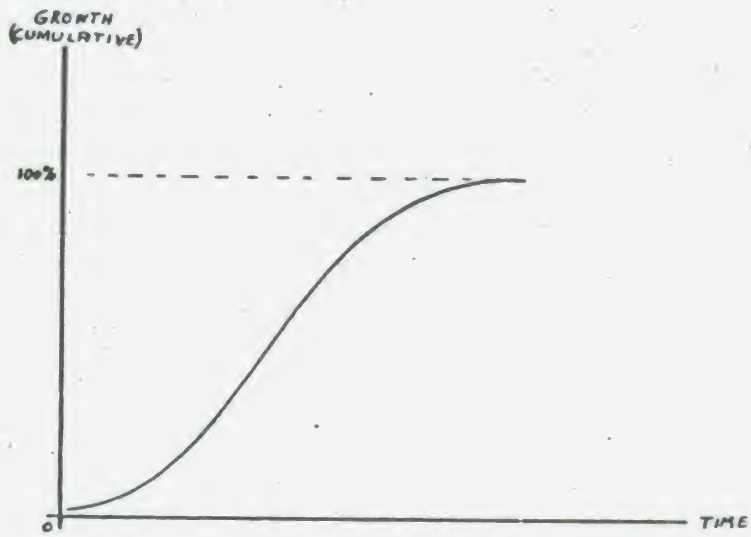

Figure 1. The Growth Curve

The growth rates of a number of developing industries were also found to follow this general format, but most attempts to use this curve form for forecasting were non-productive. The failure of the two forms of the S-shaped curve (the Logistic and the Gompertz)(See Appendix 1) to provide accurate forecasts can be attributed to two principle causes:

(1) The equation for the Gompertz curve assumes symmetry around an inflection point which is the geometric mean of the Y values, while the equation for the Logistics curve makes the same assumption for the true mean of the Y values. Neither of these assumptions is usually justified in real-world situations.[1]

(2) Because of the order of the polynomials needed to express these curves, slight perturbations of the data early in the growth process can quickly force the equation for either of the curves to forecast an unrealistically high or low figure for total growth.

This failure to accurately forecast becomes important in the context of Research and Development within the Department of Defense because R & D programs also follow the S-shaped curve form in terms of both cumulative dollar expenditures and cumulative milestone completion over time. This fact should be no surprise since the R & D process is intuitively a biological growth process in which there is slow initial development of the specific project, followed by a fairly rapid building phase which, in turn, is followed by a tapering-off to completion.

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[1]Table VI shows the actual inflection point for 21 weapon systems. Note that in no case does this point consistently fall anywhere close to either the true or the geometric mean.

The existence of these three phases in Department of Defense R & D programs was verified by taking the Cost Performance Reports (CPRs) for 22 different weapon and component systems and tracing the actual costs as they were incurred throughout the life of each R & D program. Without exception the S-shaped curve was the dominating factor in the system development as it actually occurred. The milestones associated with these programs also exhibited the same characteristics in every case for which data was available.

The results based on the original 22 weapon systems were then checked against new and very complete data which was provided by another source on 15 weapon systems. Again the connection between R & D expenditures, the S-shaped curve, and milestone completion were firmly established.

Conventional wisdom would suggest that since the Logistics and Gompertz curve forms are generally non-productive forecasting tools, one should proceed instead to construct an econometric model of the R & D process. This model, which would embody each of the endogenous variables in any given R & D project, could then use the historical cost data for each of these inputs (labor, raw materials, etc.) to establish trends. The trends could then be combined to provide an overall forecast of the final cost of the R & D project.

Unfortunately, the existing data concerning the prices of many raw materials such as aluminum, stainless steel, titanium, steel alloys, etc., are either misleading, erroneous, or simply not reflective of the true prices actually paid. In addition, labor data is often not available for the narrow categories of labor actually employed in a given R & D project, nor does it properly reflect local or regional conditions which may significantly affect wage rates.

These deficiencies rule out the use of conventional econometric modeling techniques, and one is faced with the problem of finding some known element common to all R & D programs which could be adapted as a forecasting tool.

Since the S-shaped curve is a common element in all R & D projects, this paper will deal with an effort to modify the curve in such a way that accurate forecasting can be achieved.

CHAPTER I

FITTING THE CURVE

The major problem in handling an S-shaped growth curve is one of keeping the higher-order polynomials necessary to express this complicated curve form under control. If one realizes that any S-shaped curve is merely the cumulative form of a bell curve (which may or may not be skewed) as shown in Figure 2, a solution to this particular problem becomes apparent.

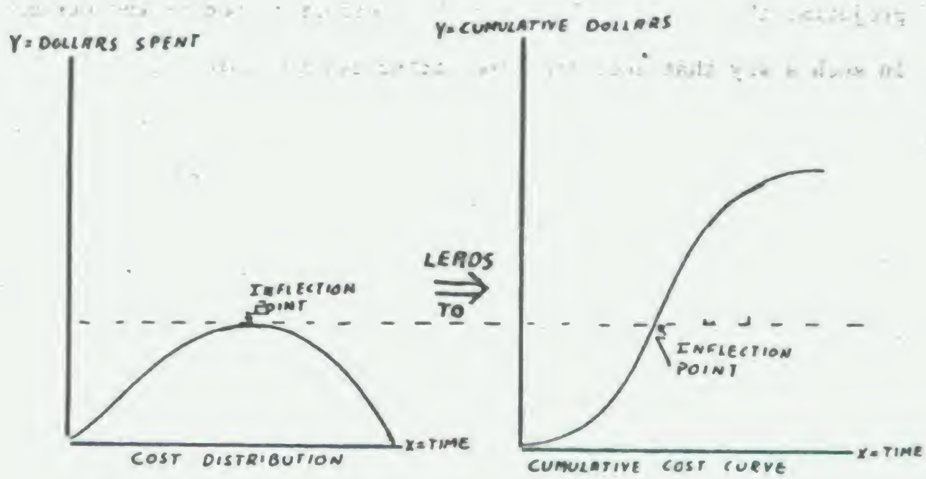

Figure 2. The Derivation of the S-shaped Curve

The S-shaped curve may be separated (or "broken") at the inflection point to yield two simpler curves of a form which may be expressed by either a logrithmic ($y = ax^b$) or a quadratic ($y = a + b_1 x_1 + b_2 x_1^2$) equation. Standard econometric fitting techniques may then be utilized to determine which of these two curve forms is the best fit.

However, the selection of the best curve form is greatly complicated by the fact that the time dependent nature of these curves, and indeed the entire R & D process, tends to cause a great deal of autocorrelation in the resulting data. This autocorrelation, which is a violation of the necessary assumption that regression residuals are not related, must be dealt with and eliminated from the data before a valid selection of equations can be made to express the lower and upper halves of the S-shaped curve. For this particular research, autocorrelation was removed through the use of Generalized Least Squares following an autoregressive transformation which utilized a two-step procedure for the estimation of Rho. This process is explained in its entirety in Appendix 2.

It should be noted that the treatment of each additional order of autocorrelation by this method removes one additional data point from the lower end of whichever half of the S-shaped curve is being considered. This occurs because each succeeding transformation steps back in time one data point further in an attempt to remove any past influences on the current regression

residual. This process has an inherent benefit in that it tends to weight more recent observations more heavily than past observations. The result is a rather sophisticated smoothing technique which may be varied according to the user's desires to assure that the fitted curves will converge rapidly on the proper values.

Tables I through IV show the results of this curve fitting technique when it was applied to both actual and budgeted cost figures for 22 major weapon systems or R & D projects. In almost every case, the quadratic equation provided the best fit of both the upper and lower segments of the S-shaped curve. The statistics accompanying each of the curve equations indicate that the upper and lower curve segments, when rejoined, do provide an excellent proxy for the original S-shaped curve for each R & D project, and the mean square error figures accompanying each equation assure that these reconstructed S-shaped curves should be useful forecasting tools.

With the curves for each of the specific programs developed, the same technique of calculating the upper and lower halves of the S-shaped curve and then mating these segments at the inflection point can be used to derive a general curve based on all weapon systems for which data is available. This general curve can then serve as the forecasting vehicle for new weapon systems.

The actual calculations for the general curve are accomplished by pooling all of the data for 17 systems. Table VI shows that the

mean inflection point for these systems occurs at the .562% of expenditures and .462% of time points with the width of one standard deviation around this point being .054% for expenditures and .073% for time. Considering that these figures were derived from a collection of systems which were so diverse as to include an early 1950's era weapon system (the F-105), cargo and bomber aircraft (C-5, C-141, B-1, etc.), engines and guns (A-10), and planned projects such as space tugs, these figures represent a surprisingly narrow confidence interval.

Exhibits I and II show the results of fitting the curve segments using a quadratic equation for both the lower and upper halves. A certain degree of heteroskedasticity was introduced into these data sets by a normalization of the data which forced the S-shaped curve to begin at the 0% time and expenditures point and end at the 100% time and expenditures point. Because of the obvious significance of the data provided in Exhibits I and II, the heteroskedasticity was not deemed to be a significant problem.

Figure 3 shows the general curve form and a 1σ confidence interval around this curve. The calculations for this confidence interval may be found in Table VI. This type of curve derivation has the obvious advantages of generating a result which should have wide application across the broad spectrum of weapon systems, and as such it will form the basis for the forecasting efforts which will be explored in the next chapters.

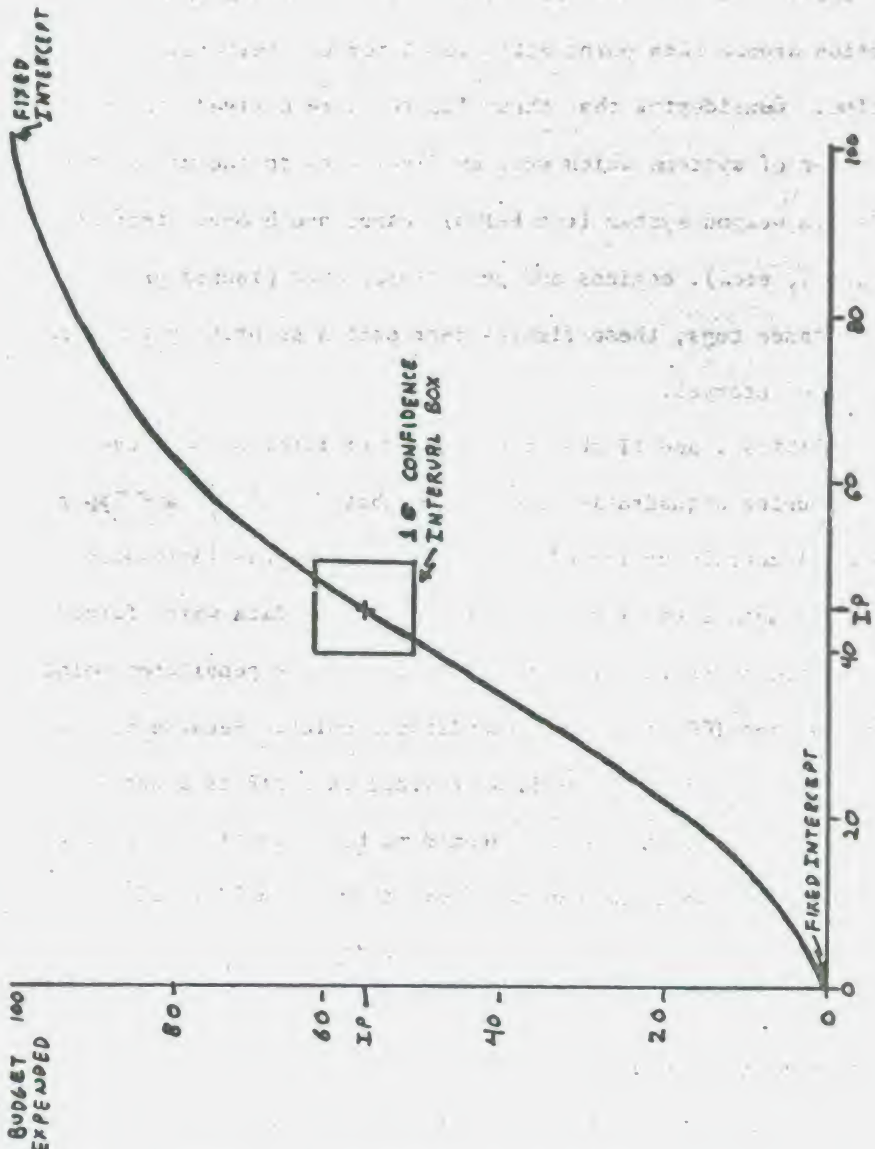

Figure 3. The General R & D Curve

CHAPTER II

THE RATIONALE BEHIND THE USE OF THE S-SHAPED CURVE

Chapter I showed that the S-shaped curve described every military R & D project which was investigated and this chapter demonstrated a practical method of finding the curve for either a specific project or a general model. However, the rationale behind the use of both a two-part curve and the initial budget data in the forecasting process deserves further explanation.

Since no one can estimate the cost to develop a new weapon system without an effort which would virtually duplicate the original contract-letting process, it is obvious that the rational approach is to accept the proposed R & D budget as decided by the contractor as the best initial estimate of the project cost.

However, once this approach is decided upon and it is realized that a two-part S-shaped growth curve can be chosen to express the program as a whole, three very interesting approaches may be adopted:

(1) The proposed project budget may be compared to all past R & D budgets to see if the expenditure pattern is generally rational in light of R & D experience with other weapon systems. Figure 3

shows the general curve with a 1σ confidence band based on the R & D projects which were studied in this paper. Considering the diversity of the weapon systems which were investigated, this band represents a fairly narrow range within which the expenditure pattern for any new R & D project should be expected to fall. If the proposed expenditure pattern falls outside of this range, the contractor should be expected tc justify why his program is unique in this respect.

(2) The proposed budget expenditure pattern can be compared to the proposed project milestones to check the specific rationality of the budget proposal. Table V shows a reperesentative selection of projects for which milestone data is available. There is a very high order of correlation between the budget expenditure pattern and the pattern in which the milestones are accomplished. This suggests that the manner in which the milestones are completed over time provides an excellent cross-check on the way in which the budget should be expended. And it also means that slips or changes in the order of milestone completion will invariably be reflected in the expenditures for the entire project.

(3) When the contractor or procurement officer considers uncertainty in any R & D program, he can generally resolve this uncertainty into different types of unknowns. Drake states that

> these unknowns are of two kinds:
> (1) The unknowns that he is aware of and believes he can resolve when he accepts a contract--for example, the configuration of

an aircraft's slats, flaps, thrust reversers, speed brakes, and other devices needed to meet the specified performance factors (take-off, landing distance, etc.).

(2) The unknowns which are bound to crop up unexpectedly and for which he is not prepared--the 'unanticipated unknowns.' Strictly speaking, they are the unknowns that *cannot* be foreseen.[1]

In other words, type 1 unknowns are known unknowns while type 2 unknowns are unknown unknowns.

If one then pictures himself standing at the beginning of an R & D project and looking down the time line toward the completion of the project, he will see the two different types of uncertainty shown in Figures 4 and 5.

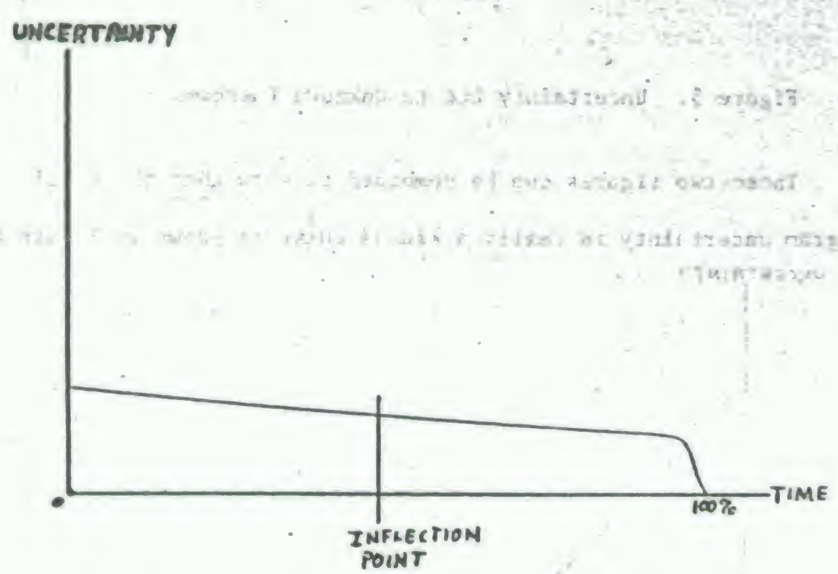

Figure 4. Uncertainty Due to Known Unknowns

[1]Drake, Hudson B., "Major DoD Procurements at War with Reality," The Harvard Business Review, January-February 1970, p. 124.

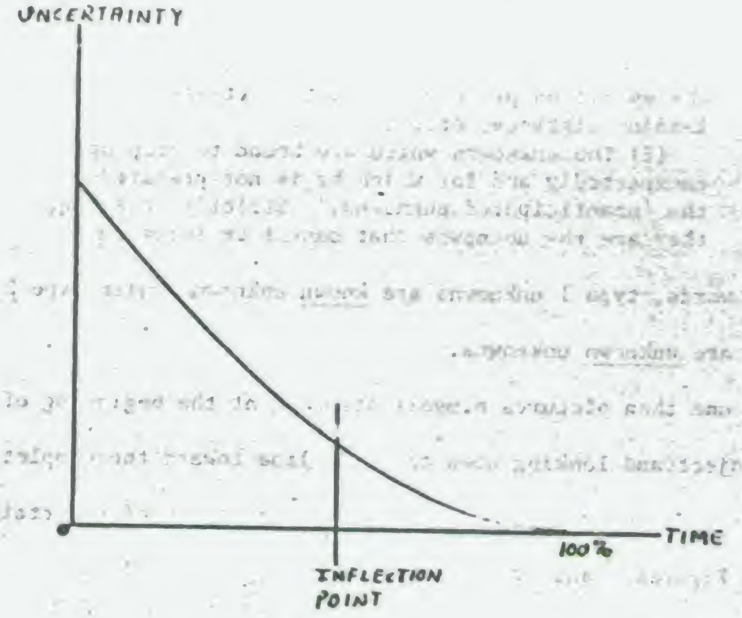

Figure 5. Uncertainty Due to Unknown Unknowns

These two figures can be combined to show that the total program uncertainty is really a kinked curve as shown in Figure 6.

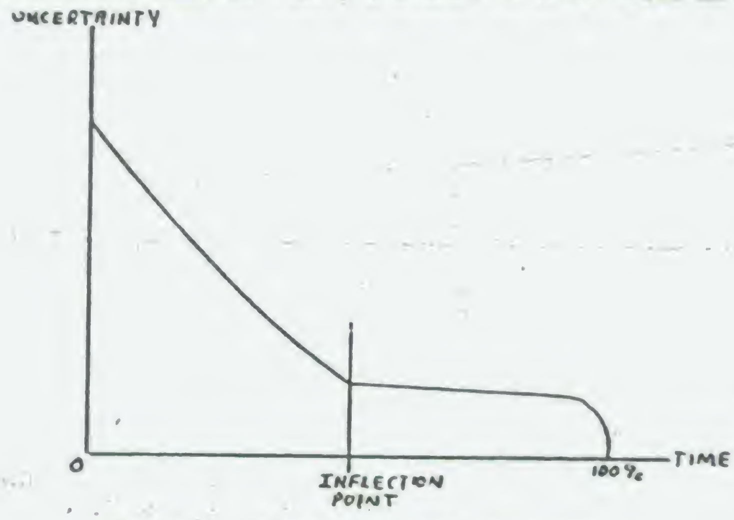

Figure 6. Total Program Uncertainty

The critical point is the inflection point of the program since it is at this point that most of the uncertainty has been dispelled. Thus, accurate forecasting is most essential and also most difficult in the early part of the R & D program. The two-part curve development overcomes the problem of changing uncertainty by allowing the researcher to forecast a new lower curve and inflection point from the actual expenditures in the program being investigated.

This forecast may then be constrained by using the top half of either the budget or the general curve in the area where uncertainty is lower and hence, these curves should be the most accurate estimators of program performance.

It should be assumed that since the contractor and the government have both attempted to plan the R & D project in the best possible manner, this planning effort should not be wholly disregarded as soon as the first actuals begin to appear. Instead, it is more rational to let the general framework of the expenditure pattern, as expressed in the budget curve, continue to represent this planning as an inherent constraint during any forecasting activity. Used in this manner, the original budget expenditure curve can be viewed as a storehouse of subjective or judgmental information which may be used to constrain a forecast and thus allow for future inputs by the managers in control of the R & D program.

These three points indicate why the use of the two part S-shaped curve is particularly appealing. Not only is the contractor subjected to intense scrutiny during the initial planning phase (points one and two), but once he passes these checks his planning may then be used as a forecasting constraint during the rest of the program.

CHAPTER III

DEVELOPING AND USING THE S-SHAPED CURVE

The general method for the development and use of the S-shaped curve for a specific R & D program follows these steps:

I. The budget figures for the R & D program are gathered and the monthly, quarterly, or other incremental expenditures are recorded as a cumulative percentage of the total expenditure. Similarly, the amount of time over which the program is to run is determined and each succeeding increment is recorded as a cumulative percent of the total program time. The time increments and budget increments must be the same. This step has the effect of normalizing the program so that it can be compared with all past R & D programs when plotted on the axis of Figure 7.

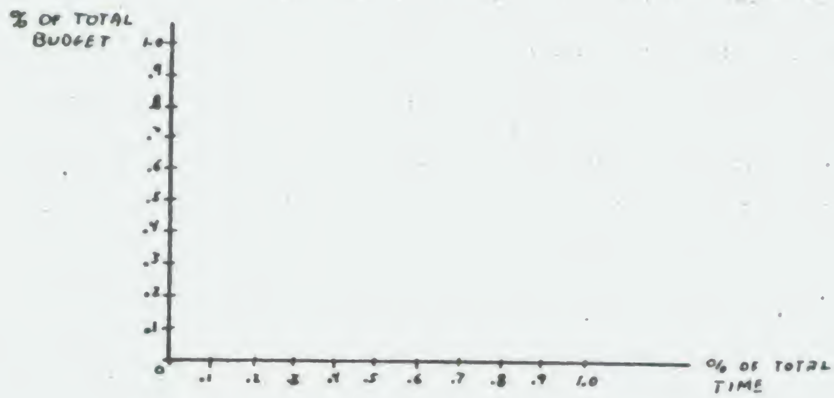

Figure 7. Expenditures vs. Time

II. With the data arrayed in this normalized format and plotted on the axis of Figure 7, the budget expenditure pattern may be immediately checked for general rationality. This is accomplished by determining whether or not the proposed budget curve falls within the confidence band which has been constructed for all past R & D projects (Figure 3). If the proposed budget expenditure pattern falls within this band, the R & D project planning is in accordance with past R & D experience. However, if the expenditure pattern falls outside the confidence band it should be determined why this particular program is planned to proceed differently than all past programs have proceeded.

III. The total number of milestones connected with all phases of the R & D project is determined and the month in which the end or completion point of each milestone occurs is noted. The cumulative percentage of completed milestones is then calculated for each period for which budget data is available. This step has the effect of putting milestone accomplishment in the same normalized form as the financial data.[1] This normalized milestone accomplishment data

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[1]At first it may seem counterintuitive to sum up milestones in the same manner in which one sums up dollars. However, even though it is obvious that no two milestones represent identical amounts of accomplishment, deriving cumulative sums of milestone completions by financial period has invariably provided an excellent picture of the manner in which the program is expected to proceed. It should be noted that the best results have been obtained when the milestones were expressed on the lowest, or most specific level available. Every attempt should be made in this process to avoid double counting between specific and general program milestones, although no adverse affects have been noted when <u>different</u> specific and general milestones were summed together using this technique.

is then regressed with the normalized budget data. The results of this regression should show an extremely significant relationship between the budget expenditures and the milestone completion. Table V shows the results for five sample programs to give a general idea of the significance of the relationship. If this relationship does not appear, the proposed expenditure pattern for the specific program in question is highly dubious and indicates an unrealistic program plan which could easily lead to financial problems.

IV. Next locate the largest incremental change in budgeted expenditures which is followed by two periods of decreasing expenditures. This increment is designated as the inflection point. The S-shaped curve is broken at this point and the inflection point becomes the last data point in the first (or lower) curve and the first data point on the second (upper) curve. This common point allows the curves to be spliced again after curve fitting. Table VI shows the location of the inflection points for the R & D programs included in the initial part of this study. Note the high degree of variability in the point locations.

V. Equations for the lower and upper portion of the budget curve are developed by the regression scheme discussed in Appendix 2. Due to the shape of the curves, a quadratic ($y = a + b_1 x_1 + b_2 x_1^2$) or logrithmic ($y = ax^b$) curve equation is usually appropriate. Particular care must be taken in this step to assure that the curve equations which are developed have dealt with the problems inherent in the use of time series data. Failure to correct the problem of

autocorrelation will result in curve equations which are of little value and which will adversely affect the performance of the completed model. To avoid this situation some techniques of the type explained in the appendix must be used at this juncture, and indeed, should be used in <u>any</u> R & D forecasting.

VI. Once the curve equations have been developed from the budget data, two specific types of knowledge have been gained:

A. The equation form which best fits the R & D budget data has now been determined. This is usually a quadratic form for both the upper and lower halves of the S-shaped curve and this specific curve form should be used with any actuals when later attempts are made to forecast the end price of the R & D project.

B. Equations expressing the subjective planning inherent in the R & D program are now available for the upper and lower parts of the S-shaped curve. These original equations can be used as constraints during forecasting, thus providing a method of incorporating this subjective information into the final price forecast. The specific methods by which the two part S-shaped curve may be used for price forecasting are the subject of the next chapter.

CHAPTER IV

THE S-SHAPED CURVE AS A FORECASTING TOOL

The objective of the methodology advocated in the first three chapters of this paper is obviously the production of a forecast cost for the system being developed. In pursuing this objective it is well to remember Scrooge's question to the Spirit of Christmas Future, "Are these the shadows of things that will be, or are they the shadows of things that may be, only? Men's courses will foreshadow certain ends, to which, if persevered in, they must lead. . . . But if the courses be departed from the ends will change."[1]

This quote conveys the proper manner in which a forecast should be employed to make it an effective management tool. The forecast should be viewed as a non-threatening means of alerting program managers to possible program difficulties and it should be presented not as a point estimate, but rather as a range of values within which the end cost of the program is likely to fall <u>if the present courses of action are continued</u>. For the purpose of this paper three points along this possible range of cost will be identified:

[1]Dickens, Charles, <u>A Christmas Carol</u>.

(a) the best possible program cost, (b) the most likely program cost, and (c) the worst possible program cost.

The best possible program cost is the cost which would be incurred by the R & D program if it is assumed that the second half of the program will follow exactly the proposed budget curve irrespective of the performance record established in the first half of the program.

The most likely program cost is that figure which would be obtained if the second half of the program follows the course indicated by the general R & D curve. This general curve being either one developed for all weapon systems such as that curve displayed in Figure 3, or a curve developed for weapon systems of the specific type of the R & D project being investigated. In other words, a curve based on general missile system data would be used when the R & D project is for a missile. Intuitively, the latter approach should provide a tighter confidence interval for the forecast.

The worst possible program cost would be the figure indicated by the upper limit of the confidence interval around the forecast. The second half of the general curve would again be used, and the confidence interval around this curve would provide the upper limit (within a certain probability) of the R & D cost.

These three types of forecasts are shown in Figure 8.

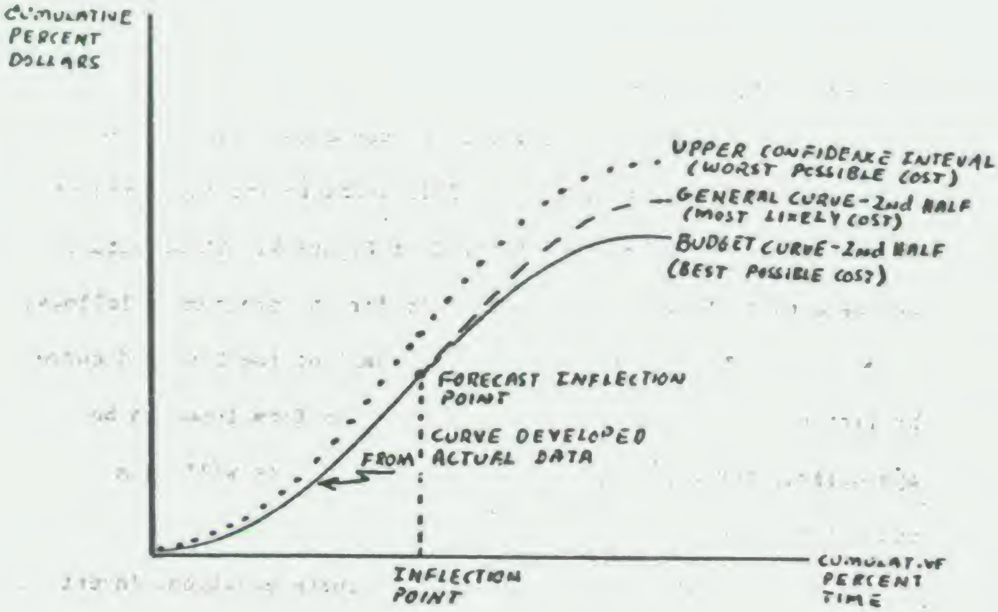

Figure 8. Three Possible Forecasts
from Program Actuals

The specifics involved in forming each of these forecasts will now be covered.

THE BEST POSSIBLE COST

(1) First derive the two halves of the equation for the S-shaped curve in the manner previously outlined. This gives curve 1 of Figure 9, the budget curve.

(2) Assume now that the first data points concerning actual expenditure information have become available. These data points are first deflated by dividing the dollar figures by an appropriate index. Studies have shown that the GNP Deflator is

usually a good choice for this index.[1] The deflated figures are then converted to percentage figures by dividing by the latest deflated total program cost, and these percentage figures are plotted on the axis of Figure 7. This leads to the beginning of an "actuals" curve, shown as curve 2 of Figure 9. These actuals may be used to forecast a new end cost for the program as follows:

(a) Derive a new lower half of the S-shaped curve by fitting the actuals to an equation of the form found to be appropriate for the budget data--in general, this will be a quadratic curve.

(b) Using this quadratic curve equation, insert the percent of total time figure for the budget curve inflection point (35% on Figure 9) to forecast a new inflection point, (Point 5 on Figure 9) and then use other points on the X (time) axis to derive a new lower half for the S-shaped curve.

(c) Now take the equation which was developed for the top half of the budget curve and substitute the percent time and percent budget figures for the forecast inflection point into this equation to calculate a new intercept for the upper curve. This new intercept, along with the original slope figures from the budget curve, has the effect of "splicing" the equation developed

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[1] Brush, John S., "Study of Possible Improvements in the Accuracy of Aeronautical Economic Escalation Indices," unpublished paper, USAF Academy, Colorado, February 1976.

from the first half actuals to the budget equation for the second half of the curve, all of which yields the new S-shaped curve 4 of Figure 9. In addition, this procedure allows the development of a forecast for the end cost of the project which is constrained by the planning and other subjective information inherent in the original budget curve.

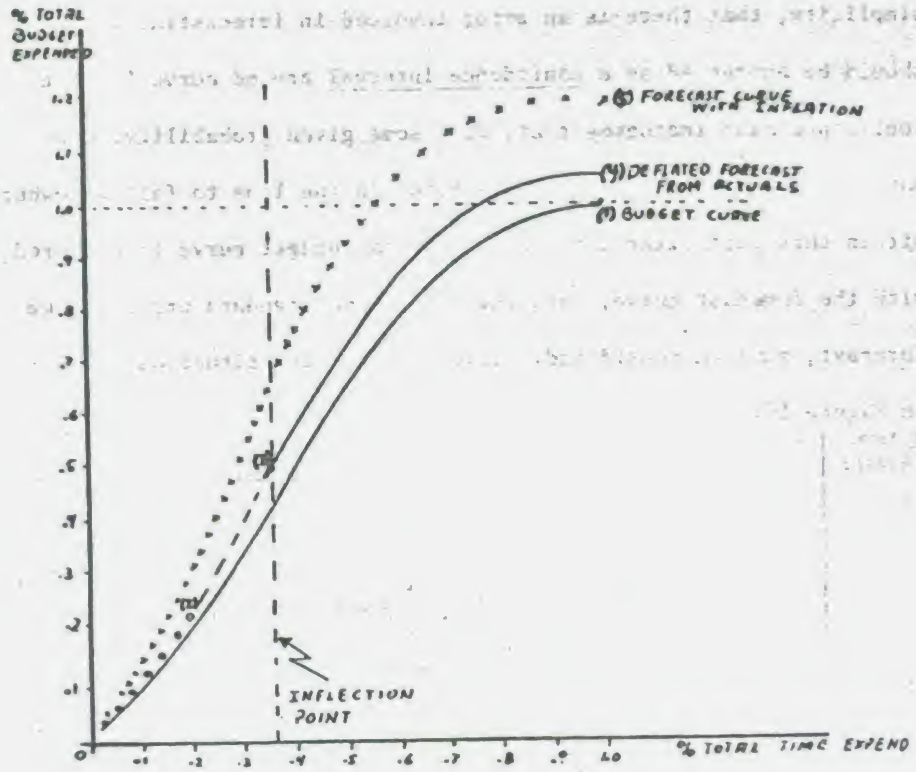

Figure 9. The Forecasting Process

(d) At this point, one may take several different approaches. First, if it is desired to learn the absolute figure for the final cost of the project, curve 4 may be modified by

inclusion of inflation data. In this case, the forecast expenditure data of curve 4 would be multiplied by an inflation index to get a new curve which is labeled 5 on Figure 9. However, in doing this one should have in mind a concept of the errors inherent in any process such as the one just described.

Up to this point we have not mentioned, for the sake of simplicity, that there is an error involved in forecasting which should be expressed as a confidence interval around curve 4. The confidence band indicates that, with some given probability, one may expect the real value for any point on the line to fall somewhere within this particular interval. When the budget curve is compared with the forecast curve, only one error, the standard error of the forecast, must be considered. This leads to the situation shown in Figure 10.

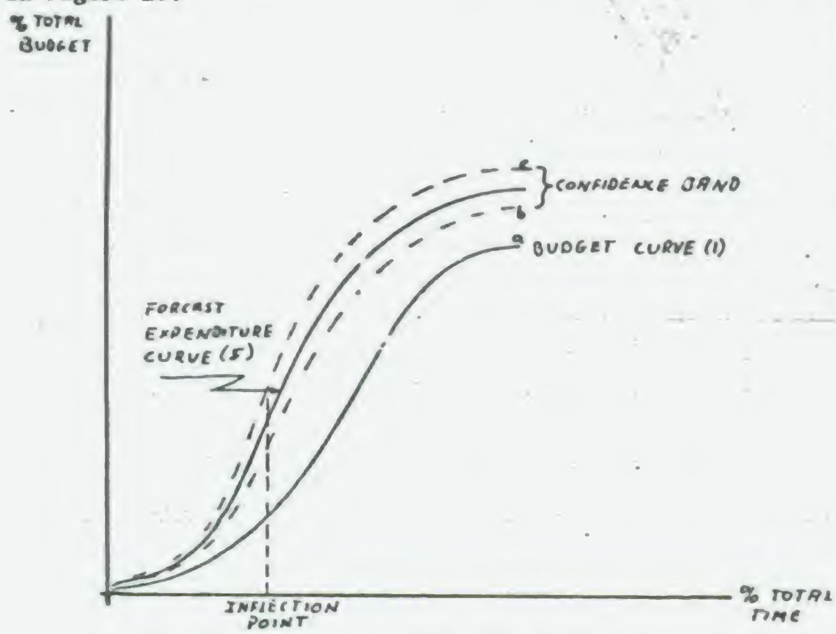

Figure 10. The Error of the Forecast

Here the confidence band indicates the possible range of values (from b to c) in which the true, deflated cost of the program is expected to fall, and similarly, the range of the size [from ab to ac] of the potential program overrun.

However, if one desires to compare the full cost, with inflation, of the project (5, Figure 9) with the full inflated cost of the budget, both the error of the forecast <u>and</u> the error involved in developing the inflation figures must be considered. This has the effect of greatly increasing the size of the confidence bands as is shown in Figure 11. The end result is that the ability to compare the final cost of the project with the budget cost is greatly impaired. As Figure 11 shows, in this case one could anticipate a tremendous overrun [a - d] and an underrun [c - b] from the same data.

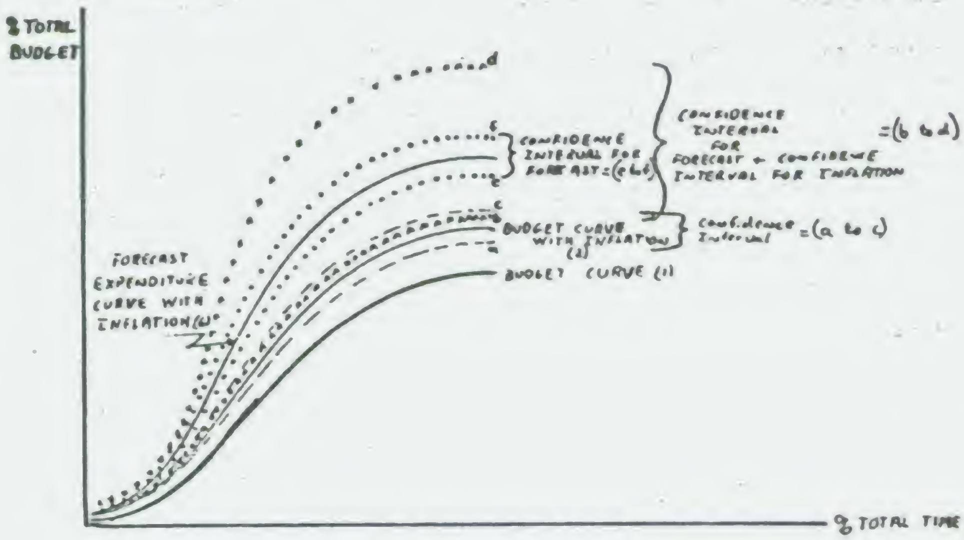

Figure 11. The Error of the Forecast and The Error of the Inflation Forecast

The lesson here is to compare figures in a manner which will minimize the errors involved in the comparison. In other words, the best picture of the status of a project may be gained by comparing the two deflated curves shown in Figure 10. This comparison provides all of the information required for day-to-day management of the program. If a full end cost of the program is desired, this can be developed quickly by simple multiplication utilizing whatever inflation forecast is deemed appropriate at the time that the information is required.

This does not mean, however, that one should not use the actual inflation data when it is available. In this case, no errors of forecast are present because the actuals in both program cost and inflation rates are known. This makes it very easy to remove the effects of inflation to see how much of an overrun is actually attributable to the contractor.

Figure 12 shows a case in which the deflated budget curve 1 is modified by the actual experienced inflation to derive curve 2. This curve may be readily compared with the contractors inflated actuals (curve 3) to determine the actual extent of the overrun [a - b].

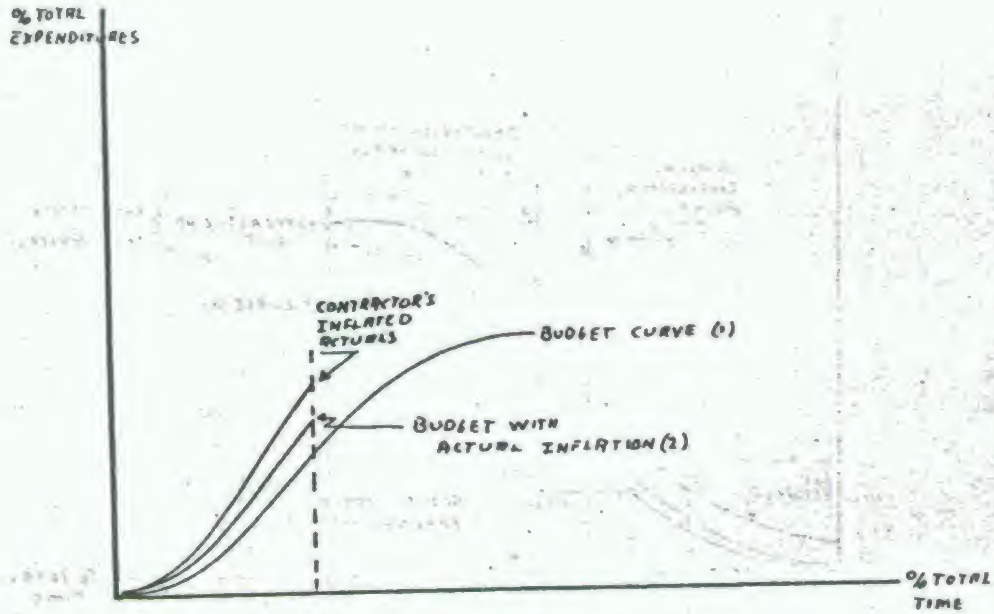

Figure 12. The Use of Actual Inflation Data

(e) Another situation which this method of program monitoring will easily handle is the case of the schedule slippage or program extension. Of the two, the slippage is the most severe because it often occurs early in the project where it has a profound effect on costs. Assume once again the basic deflated budget curve shown in Figure 13 with an actual deflated expenditure curve as shown.

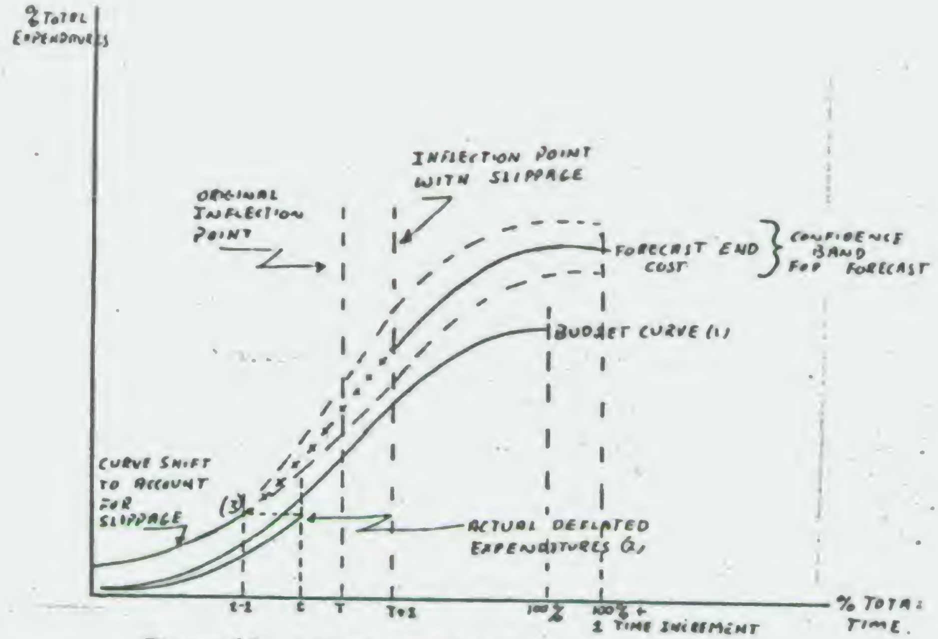

Figure 13. The Program Slippage Situation

It would appear upon initial inspection that the program is running slightly below the planned expenditures at time t. However, it is revealed that the R & D program is actually behind schedule, having only accomplished the number of milestones associated with time t-1. To compensate for this slippage, curve 2 is moved back one unit from t to t-1 so that the actual expenditures are now shown as curve 3 in their proper relationship with the budget curve. This is actually accomplished mathematically by calculating a new inflection point which will reflect the slippage in the schedule. This new point is derived from the equation for curve 2 by calculating the inflection

point not at time T, the location of the original point, but rather at time T + 1, the location of the inflection point after slippage has occurred. This new inflection point becomes the intercept of the equation for the top half of the budget curve, and the time values which are used to forecast from the top half of the budget curve now start at the T + 1 increment (instead of T) and continue to the 100% + 1 increment (instead of the 100% increment).

THE MOST LIKELY COST
(FORECASTING USING THE GENERAL CURVE)

Forecasting the most likely cost proceeds in the same manner listed in the previous section up to the point at which a new inflection point is forecast. The actuals are deflated, converted to percentages and plotted in the same manner, and the curve form to plot these actuals is the same equation type selected to describe the bottom half of the general curve. At this point, however, the method of forecasting changes considerably.

Instead of merely splicing the top half of the general curve onto the new bottom curve, the bottom curve is actually mapped into the general curve framework. This is accomplished as follows:

(1) Using the deflated actuals from the program, fit whatever curve form is used in the bottom half of the general curve to this data and forecast a new value for cumulative expenditures at the inflection point. This new value is found by substituting the cumulative percent time figure which corresponds to the

general curve inflection point into the new equation which was derived from the actuals.

(2) Take the new value for cumulative expenditures and let this value be equal to the cumulative percent of budget figure which is associated with the inflection point on the general curve.

(3) Using the relationships established in 1 and 2, the top half of the general curve may now be converted from cumulative percentage figures to forecast cumulative expenditures for the program being investigated.

This forecasting method has several advantages:

(1) The time over which the program is planned to run is taken as a given unless evidence to the contrary is discovered.

(2) The lower curve forecast is mapped into the general curve format, thereby creating a smooth S-shaped curve for the entire program. Simply splicing the curves as is done with the budget curve in the previous section will often create discontinuities in the curve.

(3) The forecast which is created in this method is based strictly on the assumption that expenditures in this particular program are proceeding in the same manner that all past programs have proceeded.

THE WORST POSSIBLE COST

Developing the forecast for the worst possible cost is only a matter of slightly modifying the previous most likely cost forecast.

A confidence interval for the most likely cost is calculated by the methods covered in Chapter V. The upper limit of this confidence band, based on whatever level of confidence was selected by the analyst, will give the cost figure that one can be XX certain will not be exceeded. Coupled with the most likely cost, this is an excellent management tool.

In summary, three possible forecasts may be developed from the S-shaped curve. The "spliced" curve forecast using the program budget curve reflects an expenditure of the lowest possible magnitude which can be obtained. For this expenditure to be realized, the program must run exactly as planned from the inflection point onward. This is a highly unlikely situation if any increased expenditures have been incurred early in the program. The most likely cost and its confidence band which extends to the upper confidence limit (or the worst possible cost) for the program are clearly the most realistic forecasts. This is because the method of mapping the new forecast for the bottom of the curve into the general curve format places the entire program in a more legitimate, historical perspective.

FORECASTING IN THE AREA OF THE INFLECTION POINT

With the general methods for handling data early in program established, the next area of interest is the forecast which is made when the string of actual expenditures stretches all the way to the assumed inflection point in the program. When this takes place two courses of action are called for as the actuals approach and cross the inflection point:

(1) Until the inflection point has been reached, the best method of forecasting is to continue to develop a new lower half of the curve from the actuals, and then to map this curve into the general curve as was done in the previous sections of this chapter.

(2) After the actuals appear to have crossed the inflection point (*i.e.*, a large expenditure in a given period has been followed by two periods of decreasing expenditures) one can proceed in two different ways:

(a) If the actual data points continue to fit the top half of the general curve within an appropriate confidence interval, continue to forecast by using the top half of the general curve.

(b) If the actual data points are diverging from the general curve, and if enough actual data points exist beyond the inflection point for regression analysis to be used, then calculate a new equation for the top half of the curve using whichever equation form was appropriate in deriving the general curve. This method presumes that <u>at least</u> 5 data points have occurred past the inflection point. It should be noted that good accuracy in generating a new curve will not occur until at least 10 points have been identified.

CONCLUSION

The general techniques concerning the use of inflation in the model and the method of handling time slippages are applied to the forecasts based on the general curve in exactly the same manner as

they were used with the budget curve. The forecasting method selected should be the one which best serves the decision maker's needs.

Since the general curve would be representative of either a mix of weapon systems or a specific type of weapon system, either of which have been completed at some time in the past, the data around which this curve is structured should be closely examined. It will be readily apparent in most cases that these completed programs all contained a certain number of changes during their R & D phases. Thus, it should be assumed that the final cost figures which are generated from forecasts using the general curve also include a like number of anticipated program changes, even if those changes are not visualized at the early stage of the program when the forecast is made.

CHAPTER V

AN APPLICATION

Project B is a weapon system whose R & D phase started in year 1. The level 6 budget which was provided by the contractor prior to the start of the R & D program contained both a total cost figure and individual figures for the categories of engineering, manufacturing and program management labor. These deflated dollar figures were extracted from the budget and normalized to a percent of total time-percent of total budget basis in Table VII. The inflection point for each of the four budget curves was also identified at this time.

The total expenditure curve was plotted on the axis of Figure 7 and compared for general rationality with the confidence band for all prior R & D programs shown in Figure 3. The proposed budget for project B was contained within the confidence band and the contractor's proposal was therefore judged to be sound.

As a second test, the total expenditure data was regressed against the project B milestones. The results of this test were as follows:

adj. $R^2 = .98$

$F = 165$ Durbin Watson Statistic: 1.97

$t = 41$

These statistics show a significant relationship between the milestones and the expenditure pattern, and, therefore, confirm the specific rationality of this particular expenditure pattern for this particular project.

Having passed these two important tests, the budget data can be assumed to be valid and equations for the top and bottom halves of both the total budget curve and each of the labor curves can be developed. Exhibit III shows the output of the computer regression runs for the total budget curve, and from this output the equations for the bottom and top halves of the curve can be found to be

$$\text{bottom half:}\quad Y = -.193572 + 1.88402X_1 + .470083X_1^{\,2}$$

$$\text{top half:}\quad Y = .149350 + 1.75834X_1 - .91088X_1^{\,2}.$$

All of the above research would be accomplished prior to the start of the program itself, and the program manager, who has justified in his own mind the validity of the budget in both a general and a specific sense, may now sit back and await the arrival of the actuals.

By the second quarter of year three, the actuals shown in Table VIII have been accumulated. Obviously, the program manager would have been forecasting the future program costs each time a new set of actuals arrived, but let us assume that this task is now to be accomplished based on the latest figures which have just arrived. First, the program manager fits a quadratic curve form to each of the strings of actuals representing the total budget and the engineering, manufacturing and program managing labor. A

quadratic is chosen for the equation form because, in each case, it was this type of equation which provided the best fit for the budget curves. For simplicity, we will only deal with the total budget curve in this example, even though the program manager would be highly interested in forecasting each of the other three curves in an actual situation.

The equation for the total budget actuals is developed by a computer regression technique, the results of which are shown in Exhibit IV. The equation is

$$Y = .00275322 - .057272X_1 + 4.84246X_1^2.$$

Figure 14 shows the actual expenditures and the budget curve for comparison.

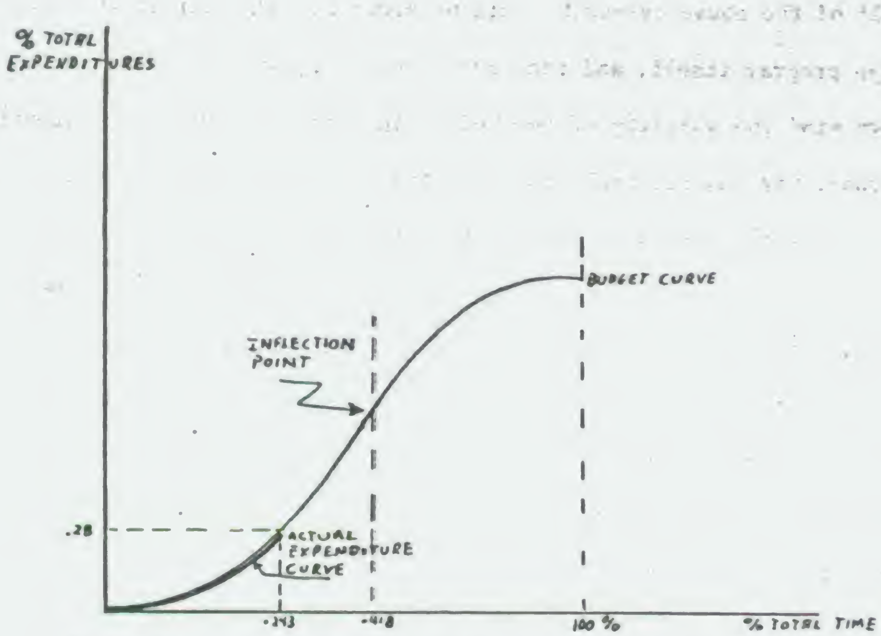

Figure 14. Actual Expenditures and the Proposed Budget

It appears from Figure 14 that the actual total expenditures are slightly underrunning the budgeted total expenditures. However, upon comparison of Tables VII and VIII, it becomes obvious that something is amiss. The engineering, program management and budget expenditures are all on schedule or overrunning while the manufacturing labor is well below the budgeted expenditure level. The program is obviously not proceeding as planned, and more specifically, the engineering and program managing efforts are not producing the necessary results for manufacturing to take place.

A further comparison of the manufacturing figures in Tables VII and VIII indicates that the program is actually about 1 period behind schedule (2 quarters).[1] This means that a slippage has occurred, and the actuals curve is shifted to reflect this condition as shown in Figure 15.

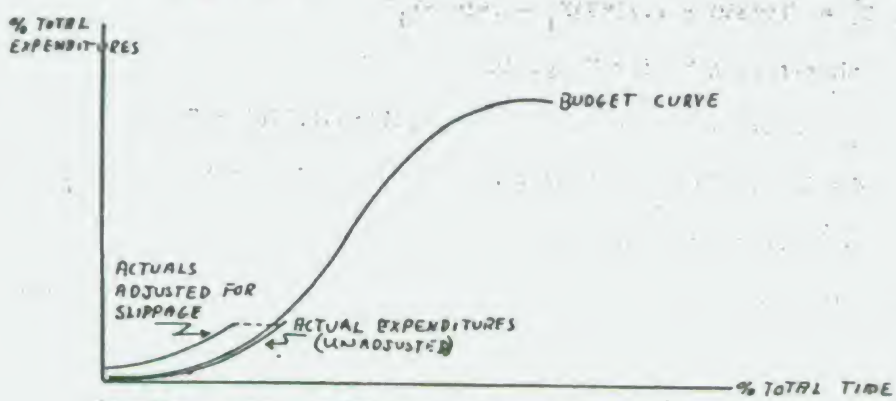

Figure 15. Shifting the Actuals Curve

[1] Note that this condition could have been detected at a much earlier time. Manufacturing begins to lag significantly by the 3rd reporting period.

FORECAST USING THE BUDGET CURVE

To determine the effect which this slippage has had on the total budget, we now forecast the end cost as follows:

(1) Forecast a new inflection point for the actuals curve by using the derived equation for the actuals and the time period for quarter 2, year 5 instead of the original inflection point (quarter 4, year 4). This mathematically adjusts the forecast for the 1 period slippage noted previously.

$\therefore$ new inflection point = Y_n where

$$Y_n = .00275322 - .057272(.476) + 4.84246(.476)^2$$

$$Y_n = 1.0726779$$

(2) Use the new inflection point to calculate a modified intercept for the equation for the top half of the budget data. From Exhibit I this curve equation is

$$Y_t = .149350 + 1.75834X_1 - .91088X_1^2$$

Substituting Y_n for Y_t yields

$$Y_n = 1.0726779 = \text{New intercept} + 1.75834(.476) - .91088(.476)^2$$

and $1.0726779 - 1.75834(.476) + .91088(.476)^2 = \text{New Intercept}$

$.4420916 = \text{New Intercept}$

Note that this value is calculated at the same inflection point used in step (1).

(3) This new equation for the upper half of the actuals

$$Y_t = .4420916 + 1.75834X_1 - .91088(X_1)^2$$

may now be used to calculate the forecast cost at any point from the inflection point on to the end of the program. To calculate the end cost of the R & D program we would proceed as follows:

(a) With no slippage the R & D program should end at the 100% of total time point. But with 1 period of slippage the program should now end at the:

(100 + 5.6)% point

where each time increment has been equal to

5.6% of the total time

$\therefore$ end cost $= Y_t = .4420916 + 1.75834(1.056) - .91088(1.056)^2$

$= 1.283143$

or, in other words, a 1 period slippage in the program has induced a 28% overrun in the final cost.

FORECAST USING THE GENERAL CURVE

Assuming once again that 1 period of slippage had been experienced in the program, the general curve may be used to forecast a new end cost as follows:

(1) The new inflection point is forecast in the same manner as before using the equation generated from the actuals in Exhibit IV:

$$Y_n = .00275332 - .057272(.476) + 4.84246(.476)^2$$

$$\text{or } Y_n = 1.0726779$$

(2) This point is now mapped into the framework of the general curve. Figure 3 shows that the inflection point of the general curve is located at 46% cumulative time and 56% cumulative expenditures. Thus, if

$Y_n = 1.0726779$, then

$$1.0726779 = 56\% \ (E)$$

where E = total program expenditures.

$$\therefore E = (1.0726779) \div .56 = 1.9153$$

and the most likely total program cost is forecast to be 191% of the budgeted cost.

(3) The method outlined in (2) can be used to fill in the rest of the points along the new forecast cost curve, but it is interesting to note that this forecast calls for a much higher figure than that produced by the budget curve "splicing" method.

THE CONFIDENCE INTERVAL

To use this forecast in its point estimate format would be an error. Rather there is a confidence interval around this forecast which must be considered. The calculation of this interval is a two-part process dealing first with the standard error of the forecast for the new inflection point. Exhibit IV shows that S^2_{yx}, the variance, is .000132813 for this particular line. The standard error of the forecast is calculated from the formula

$$S_f = S_{yx}\sqrt{1 + \frac{1}{n} + \frac{(X_o-\bar{X})^2}{\Sigma(X-\bar{X})^2}}$$

where X_o is, in this case, the inflection point.

$\therefore$ for this example

$$S_f = .011497\sqrt{1 + \frac{1}{5} + \frac{.476}{.0339}}$$
$$= .044$$

and thus one can be 95% confident that the inflection point is within

an interval of

$$1.0726 \pm t_{n-1} S_f$$

$$\text{or } 1.0726 \pm 2.776 \ (.044)$$

$$1.0726 \pm .1246$$

Figure 16 shows this confidence band around the lower half of the curve.

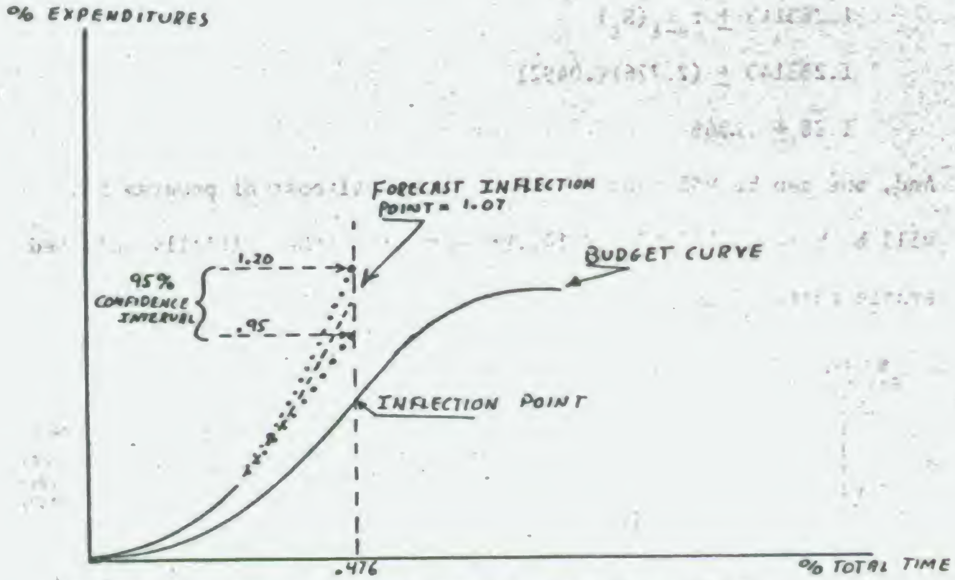

Figure 16. The Confidence Band for the Lower Half of the Actuals Curve

When the top half of the curve is spliced to the forecast inflection point an additional error, namely that of fitting the upper half of the curve to the budget data, is encountered. This fitting error can be read from Exhibit III as $S^2_{yx} = .0000271942$.

A conservative estimate for the total error involved in the forecast of the final cost can be gained by combining the forecast

error at the inflection point with the fitting error of the upper half of the curve as follows:

$$S_f + S_{yx} = \text{Total standard error} = S_t$$

$$.0440 + .0052 = .0492 = S_t$$

Thus the confidence band around the forecast for the end cost of the program using the budget curve becomes

$$1.283143 \pm t_{n-1}(S_t)$$

$$1.283143 \pm (2.776)(.0492)$$

$$1.28 \pm .1366$$

And, one can be 95% confident that the final cost of program B will be between 114.65 and 141.98 percent of the initially budgeted system cost. Figure 17 shows this completed forecast.

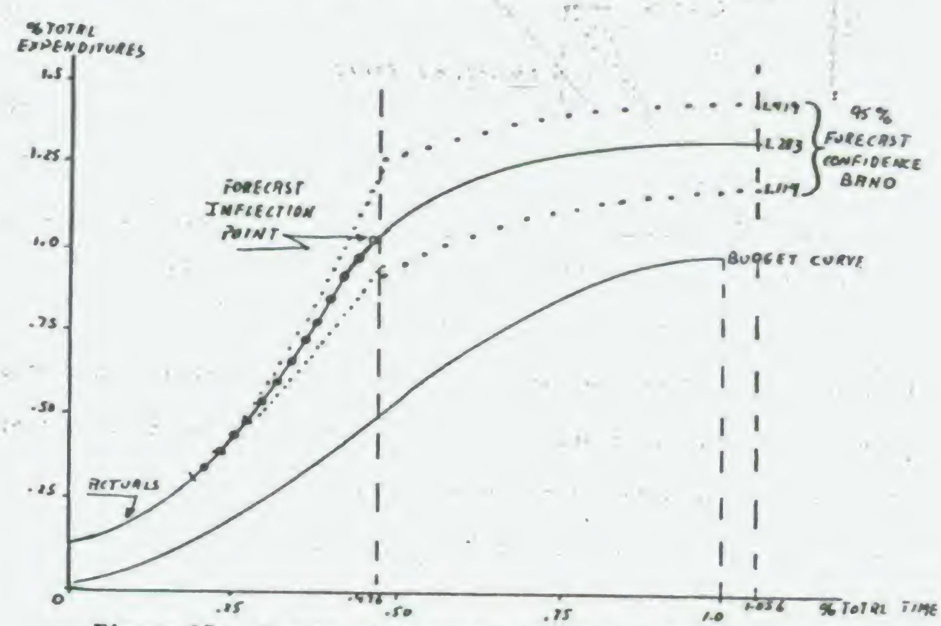

Figure 17. Completed Forecast for System B

Similarly, this process can be completed for the forecast made with the budget curve to derive the most likely cost. Here the standard error of the forecast remains

$$S_f = .044$$

as has previously been calculated. However, as might be expected, considerably more error is involved in fitting the top half of the general curve than was present in the budget curve. For this curve, composed of numerous system types, Exhibit II shows that the fitting error (S^2_{yx}) is

$$S^2_{yx} = .00746826$$

therefore $S_{yx} = .086$

and the total standard error (S_t) is

$$S_t = S_f + S_{yx}$$

$$S_t = .044 + .086 = .13$$

Now the confidence interval for the most likely cost is

$$1.9153 \pm t_{n-1}(S_t)$$

$$1.9153 \pm (2.776)(.13)$$

$$1.9153 \pm .36$$

and there is 95% confidence that the most likely cost of program B is between 228 and 156 percent of the initially budgeted system cost.

Another output of this forecast is the worst possible cost. This cost is the upper limit of the confidence interval or, in this case, 228% of the amount initially budgeted for the project.

If these forecasts seem unreasonably high, it should be noted that program B was an actual program and that the final cost for the

R & D portion of program B was quite close to the worst possible cost (228%) figure. Note also that this entire process has been accomplished with deflated data. Incorporation of the forecast inflation rates for this period would have greatly increased the size of the confidence band in Figure 17 and hence, greatly decreased the possible forecasting accuracy of the overrun.

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APPENDIX I

LOGISTICS AND GOMPERTZ CURVE EQUATIONS

The equation for the Logistic Curve is

$$\frac{1}{Y_c} = k + ab^x \text{ where}$$

$$a = (\Sigma_2 Y - \Sigma_1 Y)\frac{b-1}{(b^n - 1)^2} = \text{the difference between } Y_c \text{ at } X_o \text{ and } Y_c \text{ at } K$$

$$b = \sqrt[n]{\frac{\Sigma_3 Y - \Sigma_2 Y}{\Sigma_2 Y - \Sigma_1 Y}} = \text{the ratio between successive increments of growth.}$$

$$k = \frac{1}{n}\left(\Sigma_1 Y - \frac{b^n-1}{b-1}\, a\right) = \text{the asymptote or limit}$$

and Σ_1, Σ_2, Σ_3 refer to the first, second and third parts of the Y values.

n is the number of observations in each of the three "parts" or sections of Y values.

The equation for the Gompertz curve is

$Y_c = k_a^{bx}$ using the same formulas for k, a and b as shown above.

APPENDIX II

REMOVING AUTOCORRELATION

Given that autocorrelation exists, the observed residual term e_t is actually a combination of two errors

$$e_t = \rho e_{t-1} + \nu_t$$

where ν_t is the true error term

and e_{t-1} is the previous residual term.

Since the true relationship between e_t and e_{t-1}, ρ, is unknown, it must be estimated. Several methods are available for doing this, and this study employs the following approach:

(a) compute all of the n LS residuals

$e_1, \ldots\ldots e_n$

(b) compute the ratio of the mean product of successive residuals to the LS variance estimator

$$\text{or} \quad \hat{\rho} = \frac{\frac{1}{n-1} \sum_{\alpha=1}^{n-1} e_\alpha e_{\alpha+1}}{\frac{1}{n-k} \sum_{\alpha=1}^{n} e_\alpha^{\ 2}} = \text{the estimated relationship}$$

$$\therefore \quad \hat{\rho} = \frac{\sum_{\alpha=1}^{n-1} e_\alpha e_{\alpha+1}}{(n-1)\ S^2} \qquad (1)$$

Once this estimation has been made, $\hat{\rho}$ may be used with the Generalized Least Squares method to remove the autocorrelation from

the data. This method proceeds as follows:

Given: $Y = X\beta + e$ (2)

where e is the matrix of residuals in which autocorrelation is present. Thus for any e_t

$$e_t = \rho e_{t-1} + \nu_t$$

substituting $\hat{\rho}$ for ρ, we multiply by a "differencing" matrix

$$D = \begin{bmatrix} \sqrt{1-\hat{\rho}^2} & & & & 0 \\ -\hat{\rho} & 1 & & & \\ & \ddots & \ddots & & \\ & & \ddots & \ddots & \\ 0 & & & -\hat{\rho} & 1 \end{bmatrix} \tag{3}$$

(2) may now be transformed by (3) to yield

$$(DY) = (DX)\beta + (De) \tag{4}$$

where

$$De = \begin{bmatrix} \sqrt{1-\hat{\rho}^2}\; e_1 \\ -\hat{\rho}e_1 + e_2 \\ -\hat{\rho}e_2 + e_3 \\ \vdots \\ -\hat{\rho}e_{n-1} + e_n \end{bmatrix} = \begin{bmatrix} \sqrt{1-\hat{\rho}^2}\; e_1 \\ \nu_2 \\ \nu_3 \\ \vdots \\ \nu_2 \end{bmatrix} \tag{5}$$

the set of true error terms.

Similarly

$$DY = \begin{bmatrix} \sqrt{1-\hat{\rho}^2}\ y_1 \\ -\hat{\rho}y_1 + y_2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ -\hat{\rho}y_{n-1} + y_n \end{bmatrix} \qquad \text{and } DX = \begin{bmatrix} \sqrt{1-\hat{\rho}^2}\ x_1 \\ -\hat{\rho}x_1 + x_2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ -\hat{\rho}x_{n-1} + x_n \end{bmatrix} \tag{6}$$

Recalling that $\beta = (X'X)^{-1}X'Y$, (7)

the OLS solution of (4) is given by

substituting DY for Y and DX for X in (7) to yield

$$\hat{\beta} = [(DX)'(DX)]^{-1}\ (DX)'DY$$
$$= [X'(D'D)X]^{-1}\ X'(D'D)Y \tag{8}$$

From (3),

$$\Omega = D'D = \begin{bmatrix} 1-\hat{\rho} & & & & 0 \\ -\hat{\rho} & 1+\hat{\rho}^2 & -\hat{\rho} & & \\ & \cdot & \cdot & \cdot & \\ & & \cdot & \cdot & \cdot \\ & & & \cdot & \cdot \\ 0 & & -\hat{\rho} & 1 & -\hat{\rho} \end{bmatrix} \tag{9}$$

and the GLS solution is

$\hat{\beta} = (X'\Omega X)^{-1}\ X'\Omega Y$ which,

by (5) eliminates the autocorrelation if $\hat{\rho} \equiv \rho$.

Since $\hat{\rho}$ is an estimate, and not an exact value for ρ, it is unlikely that this process will remove all autocorrelation on the first iteration. For this reason, multiple iterations are generally used with this technique and a new $\hat{\rho}$ is calculated by equation (1) after each iteration. For n iterations

$$\sum_{i=1}^{n} \hat{\rho}_i = \rho.$$

TABLE I

QUADRATIC CURVE FIT--LOWER HALF

NAME	A	B_1	(t)	B_2	(t)	F	D.W.	$adjR^2$	MSE
A-10 System	-.0786	.699	(2.96)	.997	(3.09)	800.58	1.82	.992	.000059
Engine	-.0102	.0198	(.0717)	1.77	(5.23)	419.36	1.88	.981	.000155
Gun	-.0125	.712	(2.18)	1.17	(2.84)	537.95	1.96	.989	.000065
Milestones	-.0384	1.111	(15.49)	.498	(4.31)	3081.3	.82	.996	.00025
AGM 65 A	.0099	.5365	(1.21)	1.69	(2.31)	80.89	2.76	.975	.0029
AWACS	.0387	.9532	(8.69)	.733	(3.57)	1013.10	2.06	.998	.00015
B-1 Model 1 Cost Estimates	.7528	4.829	(12.38)	-3.498	(-8.19)	392.19	2.33	.989	.00021
B-1 Model 2 Cost Estimates*	218.729	-4842	(-8.03)	31,901	(15.68)	1328.74	1.90	.998	147.123
F 105 Milestones	.0534	.3839	(1.05)	3.526	(3.5)	137.74	2.62	.986	.000668
F 100 Milestones	.0258	.5122	(2.41)	.5411	(.922)	79.2	2.16	.963	.00026
C 141 Milestones	.0496	.2018	(1.55)	.3189	(3.93)	734.57	2.08	.997	.00022
C-5 Cost Initial Report Engineering	-.0252	1.514	(19.67)	5.594	(14.79)	13031.51	1.92	.999	.000011
C-5 Non-Recurring Cost	-.0342	.1035	(9.12)	.2478	(7.94)	3698.91	1.57	.999	.00002
XB-70	-.0306	.3080	(2.05)	1.732	(7.62)	1031.12	1.69	.996	.00021
Tug R	.1417	-1.523	(-3.71)	3.995	(6.46)	108.1	2.03	.997	.00094
Tug C	.0200	.3031	(5.81)	1.582	(17.62)	3763.39	2.64	.999	.000044
Tug E	.0232	.2418	(3.71)	1.964	(16.1)	2714.81	2.12	.999	.000057
Tug G	.0274	.2717	(4.80)	1.963	(18.55)	3769.95	2.49	.999	.000044
C-5 Quality Assurance Hours	.1719	-1.755	(-9.19)	5.04	(16.3)	848.45	2.17	.986	.000024
C-5 Production Hours	.1443	-1.686	(-10.49)	5.215	(20.42)	1576.09	2.07	.993	.000023
B-1 Engineering Labor (Budget)	-.0635	1.39	(5.66)	.6066	(1.22)	550.97	2.02	.995	.00024
B-1 P & M Labor (Budget)	-.0229	1.39	(15.63)	-.128	(-.632)	1631.24	2.13	.998	.000079
B-1 Total Labor (Budget)	-.194	1.88	(4.17)	.47	(.587)	490.26	2.13	.995	.00022
B-1 Manufacturing Labor (Budget)	-.075	.449	(.823)	3.63	(3.35)	215.29	1.78	.986	.00099

* Not Percentage Data

TABLE II

LOG FIT—LOWER HALF

NAME	A	B	(t)	F	D.W.	adjR^2	MSE
A-10 Engine	-.0073	1.80	(27.17)	737.99	1.93	.979	.00015
B-1 Model 4	.5301	2.057	(47.17)	2131.61	1.74	.996	.00029
B-1 Model 2*	11.439	3.22	(77.66)	6031.25	2.09	.999	.00071
XB-70	.8176	1.994	(16.84)	283.53	2.19	.976	.0077

* Not percentage

TABLE III

QUADRATIC CURVE FIT--UPPER HALF

NAME	A	B_1	(t)	B_2	(t)	F	D.W.	adjR^2	MSE
A-10 System	-.83	3.64	(29.97)	-1.76	(-22.79)	4312.53	2.10	.998	.000016
Engine	-1.76	5.86	(4.57)	-3.10	(- 3.95)	32.19	1.66	.795	.00028
Gun	-.66	3.60	(21.57)	-1.95	(-17.57)	1102.23	1.67	.994	.000066
Milestones	-.0881	1.94	(3.56)	- .87	(- 2.5)	78.55	1.92	.881	.00012
AGM 65 A	-.33	2.93	(5.16)	-1.64	(- 4.08)	54.12	2.88	.964	.00086
AWACS	-.5008	3.306	(14.46)	-1.8	(-11.98)	423.37	2.14	.994	.000082
B-1 Model 1 Cost Estimates	.3804	1.19	(18.19)	-.5794	(-14.13)	1335.68	2.21	.997	.0000032
B-1 Model 3 Cost Estimates	-163.377	31.46	(5.84)	-.1836	(- 4.8)	45.34	1.93	.936	1159.55
F-105 Milestones	.2225	1.1736	(11.58)	-.4080	(- 5.69)	1729.57	2.09	.998	.000084
F-100 Milestones	-.7607	3.664	(12.23)	-1.939	(- 9.07)	403.02	1.94	.987	.00060
C-141 Milestones	-1.43	4.825	(7.97)	-2.397	(- 6.29)	257.4	2.51	.987	.00028
C-5 Cost Initial Report Engineering	.4708	1.133	(8.43)	-.6069	(- 6.44)	128.76	2.04	.927	.000021
C-5 Non-Recurring Cost	.0587	1.612	(11.75)	-.6741	(- 7.49)	1011.28	1.77	.994	.000021
XB-70	-1.044	4.365	(11.21)	-2.325	(- 8.85)	450.06	1.63	.992	.00011
Tug R	-2.051	6.747	(18.39)	-3.711	(-14.86)	693.12	1.92	.996	.00034
Tug C	-.6194	3.146	(14.89)	-1.521	(-10.57)	908.54	2.36	.997	.00011
Tug E	-.3129	2.499	(22.59)	-1.185	(-16.69)	3104.38	2.42	.999	.000014
Tug G	-.4153	2.912	(12.04)	-1.501	(- 9.38)	451.56	2.17	.993	.000099
C-5 Quality Assurance Hours	-.3756	2.962	(2.86)	-1.595	(- 2.63)	7.92	1.80	.323	.000019
C-5 Production Hours	.9660	-.0948	(-.248)	.1208	(.492)	1.75	1.89	.057	.000024
B-1 Engineering Labor (Budget)	-.203	2.49	(184.4)	-1.29	(-136.09)	102,647	2.05	.999	.00000088
B-1 P & M Labor (Budget)	-.613	3.15	(19.93)	-1.54	(-15.94)	1384.46	2.00	.997	.0000081
B-1 Total Labor (Budget)	.149	1.76	(13.54)	-.91	(-10.63)	519.66	2.22	.991	.000027
B-1 Manufacturing Labor (Budget)	.523	1.06	(2.89)	-.588	(- 2.46)	13.73	1.99	.739	.00016

TABLE IV

LOG FIT--UPPER HALF

NAME	A	B	(t)	F	D.W.	$adjR^2$	MSE
AGM 65A	.02213	.342	(6.45)	41.64	2.00	.931	.00062
B-1 Model 4	-.00086	.9432	(27.97)	782.11	2.11	.988	.000058

TABLE V

MILESTONES vs. EXPENDITURES RELATIONSHIP STATISTICS

NAME	A	B	(t)	F	D.W.	$adjR^2$	MSE
F-102	-1.68	2.69	(11.64)	135.53	1.98	.971	.0011
A-10	.241	.760	(13.85)	191.76	2.13	.864	.00022
T-38	-.795	1.86	(12.0)	144.09	1.75	.973	.0028
F-104	-.0166	.865	(4.65)	21.64	2.39	.838	.0208
KC-135	-.799	1.85	(3.71)	13.79	2.00	.681	.0234

TABLE VI

INFLECTION POINT LOCATIONS

	% Expenditures or % Milestones	% Time
B-1	.5573	.3594
F-105 Milestones	.5814	.3400
C-141 Milestones	.5385	.5050
C-5 Non-Recurring	.5155	.3400
XB-70	.4659	.4431
Tug R	.5316	.5500
Tug C	.5026	.4600
Tug E	.6394	.5050
Tug G	.6626	.5050
B-1 Engineering Labor	.5169	.3590
B-1 P & M Labor	.4681	.3590
B-1 Total Labor	.4218	.3010
B-1 Manufacturing Labor	.5866	.3590
C-5 Quality Assurance Hours	.4363	.4616
C-5 Production Hours	.5246	.4769
A-10 System	.4934	.4741
A-10 Engine	.6899	.6245
A-10 Gun	.5582	.4500
A-10 Milestones	.5388	.4205
AGM-65 A	.6221	.4343
AWACS	.7011	.5050
Mean Inflection Point Locations: [The four B-1 labor categories are not included in these calculations to avoid duplication of data.]	.562	.462

Standard Error:

$$S_{time} = \sqrt{\frac{\Sigma(X-\bar{X})^2}{n-1}} \qquad S_{expenditures} = \sqrt{\frac{\Sigma(Y-\bar{Y})^2}{n-1}}$$

$$S_t = \sqrt{\frac{.0852043}{16}} = \sqrt{.0053252} \qquad S_e = \sqrt{\frac{.0466886}{16}} = \sqrt{.002918}$$

$$S_t = .0729744 = 1\sigma_t \qquad S_e = .0540189 = 1\sigma_e$$

TABLE VII

PROGRAM B DATA

PERCENTAGE OF LEVEL 6 PROPOSED BUDGET FIGURES

Q/YEAR	TOTAL TIME	TOTAL BUDGET	ENG.LABOR	MFG.LABOR	P.M.LABOR	
2/1	.0100	.001206	.001905	.000015	.001322	
4/1	.0680	.025086	.045683	.001122	.058681	
2/2	.1260	.070831	.111638	.019189	.148909	
4/2	.1850	.158547	.199698	.101142	.229059	
2/3	.2430	.284803	.313899	.251838	.315084	
4/3	.3010	$\boxed{.421767}$	.414406	.407334	.390737	
2/4	.3590	.557690	$\boxed{.516945}$	$\boxed{.586607}$	$\boxed{.468142}$	Inflect Points
4/4	.4180	.668184	.611508	.722934	.533521	
2/5	.4760	.759586	.690111	.83054	.597940	
4/5	.5340	.833228	.759773	.925338	.661209	
2/6	.5920	.874918	.818965	.955615	.722603	
4/6	.6510	.908006	.872539	.965701	.786322	
2/7	.7090	.937340	.914294	.974886	.849762	
4/7	.7670	.960294	.947851	.983690	.902436	
2/8	.8250	.978752	.974348	.992814	.940941	
4/8	.8840	.991546	.990384	.998511	.970686	
2/9	.9420	.993368	.998021	.999866	.991682	
4/9	1.000	.999999	.999999	.999866	.999999	

KEY: Percentages in blocks are inflection points.

TABLE VIII

PROGRAM B

PERCENTAGE OF ACTUAL FIGURES

ENG.	MFG.	P.M.	BUDGET
0	0	0	0
.019	.0006	.036	.024
.074	.0066	.101	.080
.174	.038	.196	.145
.282	.105	.300	.280

```
************************************************ [illegible] REGRESSION ANALYSIS ************************************************
REGRESSION SERIES TITLE: [illegible] & [illegible] EXPENDITURE PATTERN CURVE BOTTOM

THE [illegible] TRANSFORMATION FOR AUTOCORRELATION HAS BEEN APPLIED TO THE VARIABLES INCLUDED IN THE PREVIOUS REGRESSION
    ORDER OF AUTO CORRELATION:          1
RESPECTIVE ESTIMATE(S) OF RHO:  0.298[illegible]

          ***** FOLLOWING REGRESSION STATISTICS DERIVED FROM 300 OBS. INDEXED FROM  2 TO 301 *****
   DEPENDENT VARIABLE:  INDEX   LAG  TITLE
                          3      0   PERCENT EXPENDITURE
INDEPENDENT VARIABLES:  INDEX   LAG  TITLE
                          1      0   PERCENT TIME
                          3      0   PERCENT TIME SQUARED

                          INTERCEPT TERM:  ALPHA =   -.1[illegible]E-01        (RHOALPHA =   -.[illegible]E-02)
          COEFFICIENT OF MULTIPLE DETERMINATION:  R-SQUARED = 0.7[illegible]
ADJUSTED COEFFICIENT OF MULTIPLE DETERMINATION:  ADJ R-SQUARED = 0.767[illegible]    DEGREES OF FREEDOM:   4 (NUMERATOR), 299 (DENOMINATOR)
                               F-TEST STATISTIC:  F =    4[illegible]   DEGREES OF FREEDOM:   4 (NUMERATOR), 299 (DENOMINATOR)
                         DURBIN-WATSON STATISTIC:  D =    2.0[illegible]
           ESTIMATED RHO (FOR AUTOCORRELATION):  RHO =   -0.0[illegible]
                   RESIDUAL MEAN SQUARE:  SIGMA SQUARED =    .[illegible]E-02

VARIABLE     ESTIMATED              STANDARD ERROR        STUDENT T RATIO      COEFFICIENT OF               AVERAGE VALUE
INDEX        COEFFICIENT VALUE                                                 INCREMENTAL CONTRIBUTION     OF VARIABLE
    1         0.[illegible]          0.[illegible]         [illegible]          [illegible]                  0.[illegible]
    3         1.[illegible]          0.[illegible]         [illegible]          [illegible]                  .[illegible]E-01
                                                     DEPENDENT VARIABLE: AVERAGE VALUE:                     0.[illegible]
                                                                         STANDARD ERROR:                    0.[illegible]

ANALYSIS OF VARIANCE STATISTICS:
F-STATISTIC IS BASED ON THE ADDITIONAL REGRESSION SUM OF SQUARES                              DEGREES OF FREEDOM:
                ATTRIBUTABLE TO THE VARIABLES INDEXED:             F-STATISTIC:       (NUMERATOR)     (DENOMINATOR)
                                                         3             25.0[illegible]        1               299

SIMPLE CORRELATION MATRIX:
           1            3
VAR ************ ************
 1    1.0000       0.[illegible]
 3    0.[illegible]       1.0000

VARIANCE-COVARIANCE MATRIX:
           1            3
VAR ************ ************
 1    .[illegible]E-01  -.[illegible]E-01
 3   -.[illegible]E-01   .[illegible]E-01
```

EXHIBIT I

GENERAL CURVE--BOTTOM HALF

```
************************************************ ADJUSTED REGRESSION ANALYSIS ************************************************

REGRESSION SERIES TITLE: GENERAL 1 AND 3 EXPENDITURE PATTERN CURVE TOP

THE DURBIN-WATSON AUTO-TRANSFORMATION FOR AUTOCORRELATION HAS BEEN APPLIED TO THE VARIABLES INCLUDED IN THE PREVIOUS REGRESSION
     ORDER OF AUTO CORRELATION:  1
RESPECTIVE ESTIMATE(S) OF RHO:  0.[illegible]

                    ***** FOLLOWING REGRESSION STATISTICS DERIVED FROM 376 OBS. INDEXED FROM  2 TO 377 *****

  DEPENDENT VARIABLE:  INDEX  LAG  TITLE
                         2     0   PERCENT EXPENDITURE

INDEPENDENT VARIABLES:  INDEX  LAG  TITLE
                          1     0   PERCENT TIME
                          3     0   PERCENT TIME SQUARED

                                  INTERCEPT TERM:  ALPHA =  -0.[illegible]          (ANU.ALPHA =  -0.[illegible]  )
             COEFFICIENT OF MULTIPLE DETERMINATION:  R-SQUARED = 0.815732
ADJUSTED COEFFICIENT OF MULTIPLE DETERMINATION:  ADJ R-SQUARED = 0.81[illegible]     DEGREES OF FREEDOM:   2 (NUMERATOR), 373 (DENOMINATOR)
                                          F-TEST STATISTIC:  F =   8[illegible]  DEGREES OF FREEDOM:   2 (NUMERATOR), 373 (DENOMINATOR).
                                 DURBIN-WATSON STATISTIC:  D =    2.0050
                    ESTIMATED RHO (FOR AUTOCORRELATION):  RHO =  -0.095099
                           RESIDUAL MEAN SQUARE:  SIGMA SQUARED =   .[illegible]E-02

VARIABLE        ESTIMATED                                                       COEFFICIENT OF           AVERAGE VALUE
 INDEX      COEFFICIENT VALUE        STANDARD ERROR        STUDENT T RATIO    INCREMENTAL CONTRIBUTION    OF VARIABLE
   1          [illegible]              0.1[illegible]          14.[illegible]         0.[illegible]               0.[illegible]
   3         -1.[illegible]            0.1[illegible]         -11.0772                -0.[illegible]              0.313[illegible]
   2                                                      DEPENDENT VARIABLE AVERAGE VALUE:      0.[illegible]
                                                                            STANDARD ERROR:      0.[illegible]

ANALYSIS OF VARIANCE STATISTICS:
F-STATISTIC IS BASED ON THE ADDITIONAL REGRESSION SUM OF SQUARES                                 DEGREES OF FREEDOM:
                         ATTRIBUTABLE TO THE VARIABLES INDEXED:          F-STATISTIC:       (NUMERATOR)       (DENOMINATOR)
                                                                 3           122.7              1                 373

SIMPLE CORRELATION MATRIX:
           1             3
VAR ************ ************
 1     1.0000       0.9[illegible]
 3     0.[illegible]       1.0000

VARIANCE-COVARIANCE MATRIX:
           1             3
VAR ************ ************
 1    .[illegible]E-01  -.[illegible]E-01
 3   -.[illegible]E-01   .[illegible]E-01
```

EXHIBIT II

GENERAL CURVE--TOP HALF

```
************************************************ STEPWISE REGRESSION ANALYSIS ************************************************

REGRESSION SERIES TITLE: BUDGETED TOTAL VS TIME FOR THE FIRST HALF

THE DURBIN-WATSON RHO TRANSFORMATION FOR AUTOCORRELATION HAS BEEN APPLIED TO THE VARIABLES INCLUDED IN THE PREVIOUS REGRESSION
ORDER OF AUTO CORRELATION:              1            2
RESPECTIVE ESTIMATE(S) OF RHO:   0.103953   0.303817

FOLLOWING REGRESSION STATISTICS DERIVED FROM  8 OBS. INDEXED FROM  3 TO  8 ABOVE

DEPENDENT VARIABLE:    INDEX  LAG  TITLE
                         3     0   PERCENT EXPENDITURE

INDEPENDENT VARIABLES: INDEX  LAG  TITLE
                         1     0   PERCENT TIME
                         2     0   PERCENT TIME SQUARED

INTERCEPT TERM: ALPHA = -0.193372          (RHO)ALPHA = -0.172274   1
COEFFICIENT OF MULTIPLE DETERMINATION: R-SQUARED = 0.976950
ADJUSTED COEFFICIENT OF MULTIPLE DETERMINATION: ADJ R-SQUARED = 0.974916     DEGREES OF FREEDOM:  2 (NUMERATOR),  3 (DENOMINATOR)
F-TEST STATISTIC: F = 490.2611     DEGREES OF FREEDOM:  2 (NUMERATOR)  3 (DENOMINATOR)
DURBIN-WATSON STATISTIC: D = 2.1346
ESTIMATED RHO (FOR AUTOCORRELATION): RHO = -0.124536
RESIDUAL MEAN SQUARE: SIGMA SQUARED = .220607E-03

VARIABLE   ESTIMATED           STANDARD ERROR    STUDENT T RATIO    COEFFICIENT OF              AVERAGE VALUE
INDEX      COEFFICIENT VALUE                                        INCREMENTAL CONTRIBUTION    OF VARIABLE
  1        1.18802              [illegible]       [illegible]        [illegible]                 [illegible]
  2        0.47038              [illegible]       [illegible]        [illegible]                 [illegible]
                                                           DEPENDENT VARIABLE AVERAGE VALUE:   [illegible]

ANALYSIS OF VARIANCE STATISTICS:
F-STATISTIC IS BASED ON THE ADDITIONAL REGRESSION SUM OF SQUARES
ATTRIBUTABLE TO THE VARIABLE(S) INDEX(S)          F-STATISTIC:        DEGREES OF FREEDOM:
                                                                      (NUMERATOR)     (DENOMINATOR)
                          2                        [illegible]          1               3

SIMPLE CORRELATION MATRIX:
VAR           1            2
 1        1.0000       0.98846
 2        0.98846      1.0000

VARIANCE-COVARIANCE MATRIX:
VAR           1            2
 1        0.33459     -0.35789
 2       -0.35789      0.46078
```

EXHIBIT III

BUDGET CURVE--BOTTOM HALF

```
.............................................. DETAILED REGRESSION ANALYSIS ..............................................

REGRESSION SERIES TITLE: BUDGETED TOTAL VS TIME FOR THE SECOND HALF

THE DURBIN-WATSON AND TRANSFORMATION FOR AUTOCORRELATION HAS BEEN APPLIED TO THE VARIABLES INCLUDED IN THE PREVIOUS REGRESSION
    ORDER OF AUTO CORRELATION:   1
RESPECTIVE ESTIMATE(S) OF RHO:  0.217260

THE FOLLOWING REGRESSION STATISTICS DERIVED FROM 10 OBS. INDEXED FROM 2 TO 11 ...

DEPENDENT VARIABLE:   INDEX  LAG  TITLE
                        1     0   PERCENT EXPENDITURE

INDEPENDENT VARIABLES:  INDEX  LAG  TITLE
                          2     0   PERCENT TIME
                          3     0   PERCENT TIME SQUARED

INTERCEPT TERM:  ALPHA =  0.149350        CAMJALPHA =  -0.118802

COEFFICIENT OF MULTIPLE DETERMINATION:  R-SQUARED = 0.993310
ADJUSTED COEFFICIENT OF MULTIPLE DETERMINATION:  ADJ R-SQUARED = 0.991398    DEGREES OF FREEDOM   2 (NUMERATOR),  7 (DENOMINATOR)
F-TEST STATISTIC:  F =  519.6428  DEGREES OF FREEDOM   2 (NUMERATOR),  7 (DENOMINATOR)
DURBIN-WATSON STATISTIC:  D =  2.2248
ESTIMATED RHO (FOR AUTOCORRELATION):  RHO =  -0.267600
RESIDUAL MEAN SQUARE:  SIGMA SQUARED =  .271962E-04

VARIABLE    ESTIMATED           STANDARD ERROR      STUDENT T RATIO    COEFFICIENT OF               AVERAGE VALUE
INDEX       COEFFICIENT VALUE                                          INCREMENTAL CONTRIBUTION     OF VARIABLE
  2         1.79226             0.120073            [illegible]        [illegible]                  [illegible]
  3         -0.910688           .889805E-01         -10.8112           -0.875601                    0.405174
                                                    DEPENDENT VARIABLE: AVERAGE VALUE:  0.720919
                                                                        STANDARD ERROR:  [illegible]

ANALYSIS OF VARIANCE STATISTICS:
F-STATISTIC IS BASED ON THE ADDITIONAL REGRESSION SUM OF SQUARES                     DEGREES OF FREEDOM:
   ATTRIBUTABLE TO THE VARIABLES INDEXED:         F-STATISTIC:     (NUMERATOR)    (DENOMINATOR)
                                        3         113.0            1              7

SIMPLE CORRELATION MATRIX:
            2             3
VAR ............ ............
 2   1.0000       0.98527
 3   0.98527      1.00000

VARIANCE-COVARIANCE MATRIX:
            2             3
VAR ............ ............
 2   .158587E-01  -.110759E-01
 3   -.110759E-01  .791825E-02
```

111

EXHIBIT III (Cont.)

BUDGET CURVE--TOP HALF

***** [illegible] REGRESSION ANALYSIS *****

REGRESSION SERIES TITLE: ACTUAL TOTAL VS TIME

***** FOLLOWING REGRESSION STATISTICS DERIVED FROM 5 OBS. INDEXED FROM 1 TO 5 *****

DEPENDENT VARIABLE: INDEX 2, LAG 0, TITLE PERCENT EXPENDITURE

INDEPENDENT VARIABLES: INDEX 1, LAG 0, TITLE PERCENT TIME; INDEX 3, LAG 0, TITLE PERCENT TIME SQUARED

INTERCEPT TERM ALPHA = .2753228E-02

COEFFICIENT OF MULTIPLE DETERMINATION (R-SQUARED) = 0.994733

ADJUSTED COEFFICIENT OF MULTIPLE DETERMINATION (ADJ R-SQUARED) = 0.989466 DEGREES OF FREEDOM: 2 (NUMERATOR), 2 (DENOMINATOR)

F-TEST STATISTIC: F = 188.8885 DEGREES OF FREEDOM: 2 (NUMERATOR), 2 (DENOMINATOR)

DURBIN-WATSON STATISTIC: D = 2.0117

ESTIMATED RHO (FIRST AUTOCORRELATION) RHO = -0.295877

RESIDUAL MEAN SQUARE (SIGMA SQUARED) = .1325136E-03

VARIABLE INDEX	ESTIMATED COEFFICIENT VALUE	STANDARD ERROR	STUDENT T RATIO	COEFFICIENT OF INCREMENTAL CONTRIBUTION	AVERAGE VALUE OF VARIABLE
1	-.5767[illegible]E-01	0.[illegible]	-0.[illegible]	-0.[illegible]	0.[illegible]
3	[illegible]	0.[illegible]	5.327[illegible]	0.[illegible]	.[illegible]E-01
2				DEPENDENT VARIABLE AVERAGE VALUE:	0.105800
				STANDARD ERROR:	0.112280

ANALYSIS OF VARIANCE STATISTICS:

F-STATISTIC IS BASED ON THE ADDITIONAL REGRESSION SUM OF SQUARES ATTRIBUTABLE TO THE VARIABLES INDEXED:

	F-STATISTIC:	DEGREES OF FREEDOM: (NUMERATOR)	(DENOMINATOR)
3	28.39	1	2

SIMPLE CORRELATION MATRIX:

VAR	1	3
1	1.0000	0.96501
3	0.96501	1.0000

VARIANCE-COVARIANCE MATRIX:

VAR	1	3
1	.3992[illegible]E-01	-0.[illegible]
3	-0.[illegible]	[illegible]

EXHIBIT IV

ACTUALS--BOTTOM HALF

UNCERTAINTY ASSESSMENT FOR THE DEVELOPMENT CONTRACT

Lt Col Martin D. Martin, Air Force Institute of Technology
Capt William L. Glover, Air Force Business Research Management Center
Capt John O. Lenz, Air Force Systems Command

INTRODUCTION

Cost growth has been a prevailing characteristic of major weapon system development programs in the Department of Defense (DOD) for the past twenty to twenty-five years. As a consequence, a critical problem for procurement and acquisition management has been to realistically forecast program cost and to effectively administer their programs and contracts to minimize the probability of a cost growth.

The early planning phases for a new weapon system are characterized by a high degree of technical and cost uncertainty as related to the development and production of a new weapon system. During these early planning stages, cost estimates are formulated for the potential investment necessary to acquire and maintain a system. As knowledge increases and better information becomes available, initial cost estimates are revised and updated at various points of the acquisition life cycle. There are many tools available to managers and their staffs for generating cost estimates during early planning and development phases of a weapon system. However, very few of these methods include a formal technique for evaluating the magnitude of the uncertainty associated with the technical aspects of a program. These considerations form the basis of several research efforts which are the basic theme of this paper. Each research effort and its results will be described. Then, the implications of these results will be presented.

COMPLETED RESEARCH

The series of research efforts conducted at the Air Force Institute of Technology (AFIT) evolved from an entropic cost model formulated under Air Force sponsorship at the University of Oklahoma in 1971 (8). Before discussing the research studies, a brief description of the entropic cost model is in order.

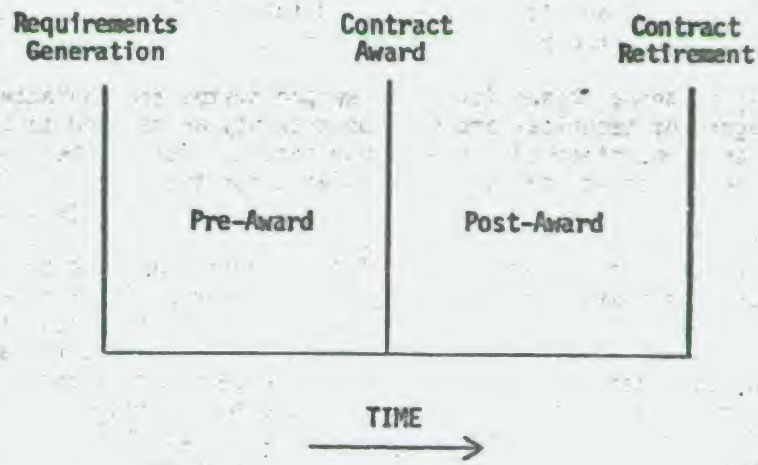
The Entropic Cost Model:

To facilitate understanding of the entropic cost model, a few points must be introduced concerning the environment relative to the development contract, that is, one awarded in the conceptual or validation phase of the weapons acquisition process.

From a contractual perspective, there are two key time periods which relate to potential cost growth: pre-contract award (pre-award) and post-contract award (post-award). (See Figure 1.)

Figure 1

Contract Life Cycle



During the pre-award time frame of the contract life cycle, management is primarily concerned with strategy formulation to deal with the development of a weapon system. Plans are made to transform these strategies into tactics to, if possible, preclude cost growth during development. To accomplish these tasks, management has at its disposal certain information that should permit the structuring of decisions at the time of award of the pertinent development contract. This information includes technical information, cost estimates, and the results of risk analysis. Technical information includes engineering estimates and feasibility studies conducted by the government or government contractors. Cost estimates are usually available from four sources: the Cost Analysis Improvement Group (CAIG); Independent Cost Analysis (ICA); the buying organization or program office (PO); and finally, defense contractors. An assessment of uncertainty is critical, however rigorous and formal treatment of this element has not been an integral part of management's information system. Only recently have serious efforts

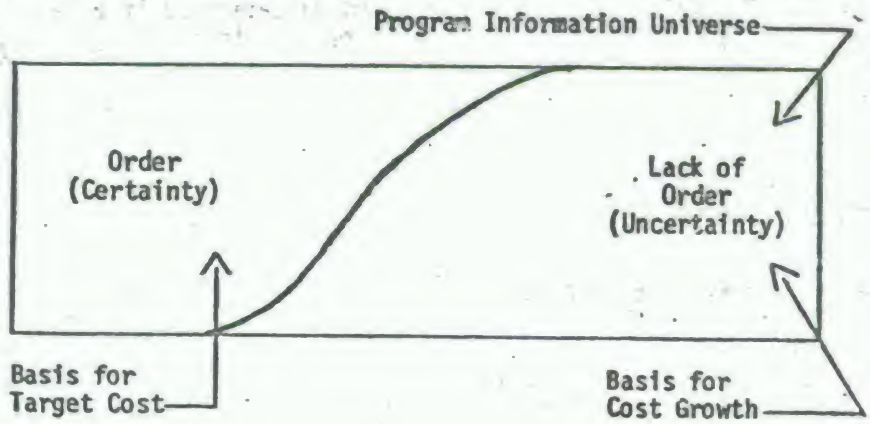
been attempted to structure the process of analyzing the uncertainty which confronts managers responsible for the development contract and the related program.

During the post-award time frame (see Figure 1), management must monitor its information system and take actions to preclude or minimize cost growth. However, the information which makes up the control base of the development contract has its roots in the pre-award time frame. The most critical point in time for model effectiveness from a planning standpoint is just prior to contract award (see Figure 1).

The information set relative to the development contract consists of two subsets: an ordered set and a set that is disordered (lacks order). The ordered set is composed of factors which appear to have certain outcomes during development. This ordered set forms the basis for the target cost (or the theoretically "most likely" cost) for the development contract. The disordered set relates to factors with uncertain outcomes and forms the basis for cost growth during the post-award time period. This information set is illustrated in Figure 2.

Figure 2

Program Information Base



The disorder, or uncertainty, in information provides the foundation for the entropic cost model. In set-theory terminology, disorder is the complement of order in the information set. For the entropic cost model, this disorder portion of the information set is approximately equal to entropy. The theory of entropy derives from thermodynamics. In a physical system, the amount of disorder is a function of its molecular state at different temperatures. The concept of entropy was extended to information systems in the development of communication and information

theory by Shannon and Weaver when they attempted to explain noise in such systems (9). The concept is further extended to form the basis for the entropic cost model which is formulated as follows:

$$\text{Final Cost} = \frac{\text{Target Cost}}{\text{Order in Information}}$$

$$= \frac{\text{Target Cost}}{1 - \text{Disorder in Information}}$$

$$= \frac{\text{Target Cost}}{1 - \text{Entropy}}$$

In the entropic cost model, when order is maximum or at unity, the final cost is certain or known with certainty. However, when lack of order or some degree of disorder is present, there are several possible outcomes and final cost is not certain. Therefore, uncertainty relates to multiple outcomes. The purpose of the entropic cost model is to estimate final cost by using a quantitative expression of the disorder or uncertainty concerning development.

The basic goal of the first two research efforts at AFIT was to test the validity of the model using simulated data from development contracts and programs. The third effort was conducted to determine if a best method was available to structure and generate data to feed the model. The following paragraphs provide a description and the results of each effort.

Glover and Lenz

Research Description. Glover and Lenz gathered data from the Short Range Attack Missile (SRAM) development program for use in testing the model (4). The researchers reviewed contract files and program documentation to determine the data availability for the test. During this review, it was found that the data (element weights) necessary to test the model was contained in source-selection files. However, these files were not readily available because of their sensitivity. Validation required the creation of the information set in existence immediately after the award of the SRAM development contract. Limited access to source selection records required the researchers to develop a method to simulate and quantify the uncertainty of information. The method had to meet the requirements of research and be potentially useful to management to capture and measure uncertainty.

The work of C. Jackson Grayson in his study of uncertainty and risk and its application to oil and gas drilling decisions was known to

the researchers (6). Jackson's technique relied on the use of probability statements by experts in oil and gas exploration and drilling relative to success in terms of production. Grayson considered both individual and group risk preferences in his work. A similar approach based on subjective probabilities was perceived to be applicable to the development contracting environment in the DOD.

Consequently, Glover and Lenz conducted an exhaustive review of the techniques available for measuring subjective opinions of experts. The review identified the DELPHI method, developed at the RAND Corporation, as the best approach to be used to simulate the development contract award environment for the SRAM. Generally, the DELPHI technique is used to solicit expert judgment to forecast what might happen in the future. Glover and Lenz used the structure and method of DELPHI to simulate what happened. They used a series of controlled interviews with feedback directed at individuals who actually participated in SRAM source selection. The researchers solicited statements of probability concerning outcome measures of unacceptable, acceptable, and exceptional for each of nine (9) factors of concern, such as range, speed, etc.

Using this approach, Glover and Lenz were able to identify some 19,683 possible factor - outcome combinations and a probability for each. The calculation base was the three categories of outcome identified during the simulation for each of the possible factors. Therefore, there were 3^9 or 19,683 possible outcomes for the development program.

Entropy was then calculated as follows:

$$\text{Entropy} = \frac{\text{System Entropy}}{\text{Maximum Entropy}}$$

$$= \frac{\sum_{i=1}^{19,683} p_i \log p_i}{\log 19,683}$$

$$= 0.686$$

Where: $0 \leq \text{Entropy} < 1$, and

p_i = probability of the i^{th} factor outcome (2).

Using the entropy value of 0.686, an estimate for total program cost as follows:

$$\text{Total Program Cost} = \frac{\text{Target Cost}}{1 - \text{Entropy}}$$

$$= \frac{\$143.3M}{1 - 0.686}$$

$$= \frac{\$143.3M}{0.314}$$

$$= \$456.4M$$

The findings that resulted from this effort were considered significant relative to the validation objective.

Research Findings. The actual cost for the SRAM development program was $439 million. The estimate for this cost obtained by applying the entropic cost model was $456 million. This estimate was based on encountering the worst possible cost conditions during development. There were some adjustments to final cost data based on approved changes which were not contemplated during source selection. Thus, the results of the study indicated that the entropic cost model had merit for use an an estimator of development cost. The unique feature of the model is its inclusion of a variable for measuring uncertainty - entropy. The results of this one research effort were not considered adequate to validate the model. Therefore, another team of researchers at AFIT, Babiarz and Giedras, attempted to replicate the Glover and Lenz approach (1).

Babiarz and Giedras.

Research Description. Babiarz and Giedras continued the effort to test the entropic cost model by replicating Glover and Lenz's work. The researchers selected the F-5E TIGER II Aircraft Development Program as their data source for the test. The procedures were identical to those used by Glover and Lenz including the use of DELPHI to attempt to simulate the uncertainty at the time of contract award. However, Babiarz and Giedras obtained results that were different from those of Glover and Lenz.

Research Findings. Babiarz and Giedras found that the application of an approach such as DELPHI did not provide evidence to substantiate the use of the entropic cost model as a forecasting tool. Their effort produced a final result that was different from the Glover and Lenz's result. Consequently, they concluded that the use of an approach such as DELPHI leaves much to be desired (1, 89).

Using the results of their uncertainty assessment, Babiarz and Giedras obtained subjective probabilities for only the "poor" (or unacceptable) and "acceptable" categories for twelve (12) factors of concern at the time of F-5E development contract award. Therefore, there were 2^{12} or 4096 possible outcomes. Entropy was then calculated as follows:

$$\text{Entropy} = \frac{\text{System Entropy}}{\text{Maximum Entropy}}$$

$$= \frac{\sum_{i=1}^{4096} p_i \log p_i}{\log 4096}$$

$$= 0.910$$

Where, $0 \leq \text{Entropy} < 1$, and

p_i = probability of the i^{th} factor outcome.

Using this result, total program costs were then calculated as follows:

$$\text{Total Program Cost} = \frac{\text{Target Cost}}{1 - \text{Entropy}}$$

$$= \frac{\$83.635M}{1 - 0.910}$$

$$= \frac{\$83.635M}{0.09}$$

$$= \$929.278M$$

The actual cost for the development of the F-5E was $89.322 million. Thus, the model forecast of total program cost was 10.4 times greater than the actual cost (1, 81). Based on this result, the researchers questioned the use of a device such as DELPHI to generate measurements of uncertainty. The problems encountered did not relate to the model, but measurement of uncertainty. Although the basic approaches used by the researchers on both efforts were the same, there were also some subtle differences which need to be discussed before describing the last research effort which specifically addresses measuring uncertainty (5).

Lanclos' Critique of Previous Efforts.

Lanclos critiqued the application of DELPHI to simulate uncertainty at the time of contract award (7). Lanclos treated the two efforts as case studies and assessed the differences between them. The following is a discussion of Lanclos' study findings (7, 9-11).

Glover and Lenz selected four persons as their expert panel who were actually members of the SRAM Source Selection Evaluation Board (SSEB). Further, Glover and Lenz followed up their research effort by gaining access to SRAM SSEB files and were able to verify their uncertainty assessments in all but one area of concern. Therefore, the team was strongly confident in the assessment.

Babiarz and Giedras decided to use the DELPHI approach from the start of their effort and did not attempt to review SSEB files for the F-5E. Their panel members were not members of the F-5E SSEB, but had managerial positions in the F-5E program office during the development of the F-5E, one of which had to drop out of the assessment due to a temporary duty assignment. Babiarz and Giedras also asked for concerns during development, not at contract award. Some of the areas of concern identified occurred as late as two years into the F-5E development program.

Having studied the significant differences between the first two efforts to test the entropic cost model, Lanclos concluded that both efforts would have been more realistic if they had been conducted "real-time." Also, Babiarz and Giedras' choice of experts and problem areas did not give a true representation of the uncertainty in F-5E development at the time of contract award. Finally, the validity of DELPHI as an approach to measuring uncertainty was not proved or disproved by either effort. However, its use to structure the assessment of uncertainty does have merit (7, 11-12).

The concern of measuring uncertainty was addressed by a third research effort at AFIT in 1976 (5).

Grayson and Lanclos

Research Description. Grayson and Lanclos' research objective was to evaluate existing techniques for assessing subjective probability (5, 9-10). Their objective was to propose an approach to assess and measure the uncertainty which existed relative to a given weapon system development. Their study addressed the following research question: "What existing subjective probability assessment technique would best

assess the magnitude of uncertainty in a given weapon system's development effort"? Grayson and Lanclos conducted an in-depth review of the critical literature available concerning techniques and methods for assessing risk and measuring uncertainty concerning future events. In their study, the researchers considered the statistical and psychological aspects of subjective probabilities and applied content analysis to six techniques for assessing subjective probabilities which have been used in the past. These techniques are:

(1) Choice-Between-Gambles

(2) Standard Lottery

(3) Modified Churchman-Ackoff

(4) DELPHI

(5) DeGroot Consensus

(6) Direct Estimation

The study included a description of each technique and an application to an example. Each technique will be briefly described for reference purposes.

The Choice-Between-Gambles is a technique that employs betting-type situations relative to gambling in an attempt to obtain probability and cumulative density functions. To accomplish this, experts are offered choices between a "real-world" gambling situation which includes values for an item with unspecified probabilities and a hypothetical situation about two outcomes with probabilities specified. A series of iterations that include varying probabilities are conducted to derive the density functions desired.

The Standard Lottery is a technique for deriving a probability density function whicn covers all possible values of a given item characteristic. It is similar to the Choice-Between-Gambles in that it is used to present an expert with two gambling situations. But it also differs from the Choice-Between-Gambles as it does not involve varying probabilities during the iteration process until a point of indifference is reached. The technique involves selecting a number of lottery tickets from a pool of 100 that is varied to achieve the point of indifference. The expert can chose as many as he wants. After the choice is made, a ticket is drawn at random. The lottery is used as a standard comparison to assist the expert to decide on a probability value for a certain outcome which relates to a characteristic of performance for an item.

The Churchman-Ackoff technique does not use a gambling-type situation or a level of indifference concerning characteristics or

outcomes. The expert is confronted with evaluations using judgments that require ranking of relative probabilities between sets of values. For example, "greater than," "equal to," or "less than" choices are used. The expert must decide ranges of possible values for "real-world" events and these are then converted to a probability density function (5, 30-33).

The DELPHI technique is used to solicit group consensus about possible outcomes or events in the future. Members of the group of experts are not privy to the other participants' identities. This feature minimizes the possibility of dominant personalities and group pressure in obtaining final results. The method involves rounds of interrogation which include controlled feedback between rounds. Each participant can change his previous choice based on the feedback from each round. These iterations continue until no change occurs. The results are then used to assess and form a measure of group consensus.

The DeGroot Consensus technique also uses experts to reach a group consensus. However, each member is required to evaluate a probability for an unknown value of a parameter. Then each participant is exposed to the inputs from other participants and revises his own judgment after assessing the others' importance, expertise, etc. This process continues until no more changes occur (5, 39).

Direct Estimation involves an estimating effort that gives it its name; each expert approximates or estimates probabilities directly with no exposure to other probabilities or situations. These results are used directly to derive a probabilities distribution for future events or outcomes (5, 40).

Research Findings. Grayson and Lanclos applied content analysis to each technique studied to determine which technique(s) was(were) commonly used for measuring uncertainty. The researchers found that DELPHI has been widely critiqued in the literature, and its use is widespread and popular.

The team also found that critical analysis and testing of the six techniques were fragmented and lacked continuity and consistency. Based on these findings, Grayson and Lanclos recommended that a series of tests be conducted to determine which techniques or combinations thereof apply to measuring uncertainty for weapon systems development. They suggested that the entropic cost model could be used to measure and compare the results of these tests.

Overall Conclusions from Completed Research

Obviously, validity testing of the entropic cost model is not complete. The Grayson and Lanclos effort supports DELPHI as a popular and widespread

tool for measuring uncertainty. But, popularity and widespread use does not indicate that a technique is the "one best way." However, the research does provide some implications for procurement and acquisition researchers and managers. These implications provide a logical baseline for early identification of uncertainties concerning outcomes for weapon system development. Once uncertainty is known to exist concerning development, management can better use its information base to deal with risks related to the uncertainty. Development of such a capability presents a challenge to our researchers and managers.

IMPLICATIONS AND CHALLENGES

Although intensive and widespread, research has not progressed to the point of providing management with an effective set of tools for realistically forecasting the ultimate cost of a new system. Costing methodologies vary and few emphasize the formal use of methods for capturing and measuring technical uncertainty. The problem of quantifying uncertainty requires further research and testing. The research challenge is to invent, design, and innovate methods for quantifying uncertainty to feed models such as the entropic cost model. These efforts will be difficult at best; there will be failures and hopefully successes. However, this series of research efforts have implications for management also. The qualitative aspects of the research may be useful for structuring the assessment evaluations of doubt, reviewing status, and improving planning baselines. Before discussing these implications, let's first address the research challenge.

Research Implications and Challenges

Procurement and acquisition processes have been the topics of a sizeable portion of business literature. A good portion of the literature that criticizes these processes is accompanied by suggested alternate approaches. But, those authors which criticize for that purpose alone must be questioned as to motive. However, some criticisms are justified. Business environments are not discrete like those of the physical sciences and are much more difficult to comprehend and measure. Since the future is difficult to forecast, it is certain that cost growth, as related to new and untried program concepts, and technology have a high probability of occurrence.

Models which are now used for estimating development and production costs usually apply historical data to forecast the future. In most cases historical data does exist and statistical tools are available to transform the data into meaningful information about what one can

expect--assuming that the future will behave similar to the past. Such methods are fairly well tested and understood by our cost analysts, price analysts, contract managers, and program managers. However, some of our analysts and managers become so engrossed in their tasks that they are vulnerable to many of the pitfalls of their jobs and environment without realizing their predicament until it becomes a real problem. Many of these problems have their roots early in the life cycle of a system. Our processes demand that variables and factors have measurements which can be translated into dollars. If a data base (as we know it) from the past is available, we have the tools for forecasting. But, the underlying implication of the series of research efforts discussed earlier in this paper concerns a different data base.

The contention of the researchers is that experts' knowledge and experience are, or are part of, a data base. Researchers have a unique challenge to develop and design methods and techniques to capture that knowledge and experience and document the results for application to new developments. We need to design data bases which can be used by management to assess uncertainty and to estimate program costs. First, a qualitative baseline of factors should be addressed--some researchers are uneasy with elements of a problem or study that cannot be readily quantified. The history of mathematics reveals many such problems. Theory is often difficult to quantify. However, there are also breakthroughs recorded in the study of our so called purest of sciences. These breakthroughs did not occur overnight--but some were accidents.

To meet this data base challenge, designers should at first consider the qualitative aspects of uncertainty. The first step should be to qualify what is uncertain and then apply a logicially structured approach to measure the uncertainty. A potential tool is the entropic cost model. However, methods should be based on simplicity. Figures 3a and 3b illustrate a conceptualization of the challenge.

Figure 3a

Research Challenge

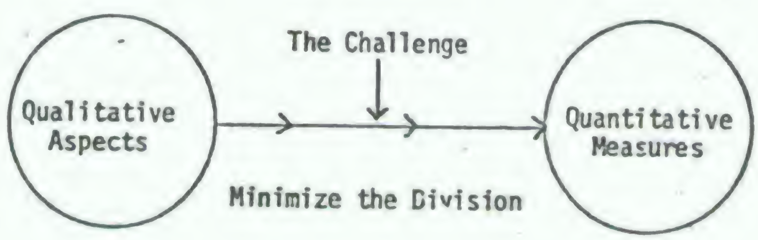
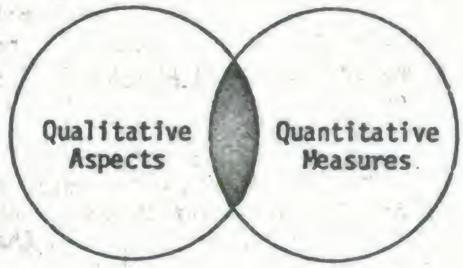


Figure 3b

Research Objective



Objective - Match the qualitative aspects with a quantitative measure for uncertainty.

Therefore, Grayson and Lanclos were on the right track : addressing what's available for measuring uncertainty. The series of tests would have continued possibly on a hit-and-miss basis. Each approach studied by Grayson and Lanclos depends on an initial qualitative exercise to identify factors or aspects of the future which are uncertain to the evaluators and experts that are familiar with the development program. Researchers should also be ready to "translate" their efforts to "real-world" possibilities. This "real-world" is where our operators and managers live and work--they should be the benefactors of research and need to be supplied with tools that work. The series of research studies also have a "message" for management based on the qualitative nature of the techniques studied by Grayson and Lanclos.

Management Considerations

Each of the techniques for assessing and measuring uncertainty which were studied by Grayson and Lanclos depends on identification of areas or factors that have uncertain outcomes. These areas should be solicited from program participants early in the planning cycle prior to contract award. Procurement and acquisition tools already exist for documenting concerns. Current directives specifically address minimizing uncertainty and risk (3, 6) during the acquisition cycle. Uncertain factors should be identified early. Such an exercise provides a structured approach to capturing the judgment of managers, evaluators, and experts; key participants usually have a knowledge and experience base that they draw on to "judge" and in turn identify concern or uncertainty based on available

information. Management could do well to capitalize on this knowledge and experience by soliciting participant concerns and uncertainty early in the pre-award planning. This effort should be a combined exercise by both the contracting officer and program manager supported by their functional staff. One major criticism of such exercises is that of time--but some time spent early may have some long range payoffs in terms of readiness to respond to contingencies during development and to minimize downstream costs.

Once this "uncertainty baseline" is established, it could be updated at major milestones during performance of the development contract. Such an approach could also benefit the staff in preparing for major system milestones required by addressing such factors in the Decision Coordinating Paper (4).

The baseline should be updated immediately after development contract award to capture specific information relevant to the particular contractor(s) involved and evaluator's beliefs in their capability to perform the contract.

The thrust of the implications are not really new. But the main purpose of this discussion is to prompt management to use their talent and ability to establish such a baseline for dealing with uncertainty. The ultimate benefits should be obvious: better visibility and understanding of uncertainty assessment problems which are encountered by contract and program managers. A structured "audit trail" should help managers to get at the "root cause" of some of our problems and treat them accordingly.

If a problem is identified which cannot be treated readily, at least the researcher can shed some light on an approach to help better address the problems and issues at hand. This approach takes time, but the potential payoffs may greatly exceed the investment.

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ESTIMATING, PRICING AND NEGOTIATING

ANALYSIS OF COST AND NON-COST NEGOTIATED PROFIT

FACTORS IN DEPARTMENT OF DEFENSE CONTRACTING

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The actual text of LTC Boyett's talk was not available for publication. The following is, however, a shortened account of that talk.

Defense Department profit policy is interpreted both at the development of the profit objective point in the procurement process and at the conclusion and documentation of the negotiated results point. This raises the question, therefore, of how DOD buying activities have been implementing DOD profit policy. To investigate this important policy parameter, a research effort was developed to provide an answer to the question: What are the relative contributions of cost and non-cost profit factors of the individual procurement action to the DOD profit objective and the negotiated profit reported on Department of Defense (DOD) negotiated procurements?

To investigate the research question, a data base was assembled from information collected by the Assistant Secretary of Defense (Comptroller). Basic information was taken from the Defense Department's report of individual contractor profit plan, DD 1499, which is prepared on every contract over $200,000 by the procuring contracting officer at the time negotiations are completed.

To reduce computational requirements and insure a relevant data base, the original data base which covered fiscal years 1959 through 1975 was reduced to the top 50 contractors by dollars awarded for fiscal years 1973, 1974, and 1975. To insure that the data base would represent the majority of situations in which DOD profit policy was applied, tests were run on the number of documents, as well as the number of dollars awarded to contractors.

In summary, the analysis found the following to exist with regard to the cost and non-cost parameters provided by Department of Defense policy for use in establishing contract profit objectives:

1. Cost input to total performance, CITP, is the largest single factor contributor to the DOD profit objective.

2. Cost risk, the second most frequently used factor is also the second largest contributor to DOD profit objectives (Tables 6 and 7).

3. Among the most frequently used contract types, FFP, FPI, and CPIF, cost risk has been widely employed in addition to cost input to total performance (Table 6).

4. The statistical model explains 77% of the variance in negotiated profit percentages using only the factors prescribed by DOD profit policy.

5. Adding the contract type, contractor, and purchasing organization to the statistical model increased the model's explanatory power by less than 4% collectively.

6. Increases in the CITP factor tended to be offset by increases in the other factors.

7. Decisions to employ or not employ a given profit factor do not appear to influence negotiated profit levels.

8. Use of profit factors varies between contract types.

9. The selected factors and special profit factors of DOD profit policy are used infrequently, and when used, account for only slight amounts for the DOD as a whole.

10. There is no evidence to suggest that the cost risk, past performance, selected factors, or special profit factors, when used, significantly influence either the magnitude of DOD's final negotiated profits with industry or the allocation of profits among contractors.

For the Department of Defense as a whole the findings indicate a cost-based policy tempered slightly by judgmental applications of risk, past performance, etc. This means that cost and its definition is the most significant single influence on profit objectives and outcomes.

A Major finding of this study indicates that when they are used the five profit factors influence negotiated profit. Cost imput to total performance is by all tests the dominant influence. This finding implies that attempts to influence negotiated profit must be coupled with policies relating the use of profit factors which are precisely worded and logically constrained within desired limits.

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Throughout DOD and the Federal Government, there is little formal guidance available to assist contract administrators in the administration of the fiscal aspect of Cost (CR) and Cost Plus Fixed Fee (CPFF) procurements. And what little DOD-wide formal guidance there is does not provide too useful a basis of the resolution of problems that invariably arise. At the Air Force Flight Test Center, I have developed a simple method of documenting and providing for the resolution of costs associated with overruns, constructive changes, additions, and deletions to the statement of work of CR and CPFF contracts. The method applies to forward and retroactively priced change orders, and supplemental agreements. Before the implementation of this method, each contractor had a different method of proposing costs. This lead to a great deal of confusion on the part of both contractors and Government administration personnel. Casualties of this process included: inadequate P.L. 87-653 (Truth in Negotiations Act) documentation; lack of clear understanding by both parties of the real problem and the associated impact on cost; unwillingness to address the real issues; etc. I believe that cost-plus-a-percentage-of-cost (CPPC) situations arose, were proposed and negotiated due entirely to an unintentional lack of understanding and disclosure. I have also found that the DD Form 633-5 which is the primary vehicle provided administrators in contract changes does not provide a method to clearly address problems or to insure that any previously unidentified problems are resolved before changes are negotiated to CR and CPFF completion contracts. Indeed, I consider the 633-5 method as presently shown by that form to be useful <u>only</u> in FFP contract changes. It has been my experience that the proposed method identifies problems, and provides a simple avenue for resolving complex contract modification situations.

1. THE BACKGROUND: Pertinent to the subject is a discussion of the underlying factors influencing administration of CPFF completion contracts as administration relates to the resolution of fiscal problems.

a. The Armed Services Procurement Regulation sets the tone of CPFF procurement in 3-405.6 as follows:

> The cost-plus-fixed-fee contract is a cost reimbursement type of contract which provides for the payment of a fixed fee to the contractor. The fixed fee once negotiated does not vary with actual cost, but may be adjusted as a result of any subsequent changes in the work or services to be performed under the contract...
>
> The Completion form is one which describes the scope of work to be done as a clearly defined task or job with a definite goal or target expressed and with a specific end-product required. This form of contract normally requires the contractor to complete and deliver the specified end-product (in certain instances, a final

> report of research accomplishing the goal or target) as a condition for payment of the entire fixed-fee established for the work and within the estimated cost if possible; however, in the event the work cannot be completed within the estimated cost, the Government can elect to require more work and effort from the contractor without increase in fee provided it increases the estimated cost.

CR type contracts, and more particularly CPFF contracts are frequently termed 'best efforts' contracts. This term is generally taken to mean that a contractor is expected to diligently pursue completion of the required effort within the funds allocated. However, if during performance it appears that funding beyond that originally contemplated will be required, the contractor is not obliged to continue performance beyond the face value of funds provided.

b. Three clauses are the primary vehicles in the administration framework. The first are the CHANGES clauses for cost reimbursement use, primarily ASPR 7-203.2 and 7-404.1. These two clauses are essentially the same for our purposes. The applicable portions are as follows:

> If any such change causes an increase or decrease in the estimated cost of, or the time required for, the performance of any part of the work under this contract, whether changed or not changed by any such order, or otherwise affects any other provision of this contract, an equitable adjustment shall be made:
>
> (i) in the estimated cost or delivery schedule, or both;
>
> (ii) in the amount of any fixed fee to be paid to the Contractor; and
>
> (iii) in such other provisions of the contract as may be so affected, and the contract shall be modified in writing accordingly...
>
> ...Until such modification is made, the Contractor shall not be obligated to continue performance or incur costs beyond the point established in the clause of this contract entitled "Limitation of Cost" or "Limitation of Funds".

In this vein, the Board notes in *Sterling Precision Corp.*, ASBCA No. 4646, 59-2 BCA 2371 that

> ...The cardinal difference, albeit not the only one, between the fixed price contract and the CPFF type of contract before us is that under the latter, the contractor is not obligated to continue performance or to incur costs is excess of the cost estimated

beforehand and stipulated in the contract. The effect of this provision generally, if the Government does not provide additional funds, is to excuse the contractor from failure to perform under the CPFF clause entitled "Excusable Delays".

The changes clause makes two points:

1. negotiate an equitable agreement in cost and fee, and

2. the contractor is not required to perform or incur costs beyond the estimated cost set forth in the Schedule, which is referred to by the Excusable Delays clause.

The clause itself, and the Board's decisions lead into the other two clauses.

c. The EXCUSABLE DELAYS clause, ASPR 7-203.11, uses such terminology as to generally excuse the contractor from termination for default because of failure to perform the required work.

> ...the Contractor shall not be in default by reason of any failure in performance of this contract in accordance with its terms (including any failure by the Contractor to make progress in the prosecution of the work hereunder which endangers such performance) if such failure arises out of causes beyond the control and without the fault or negligence of the Contractor. Such causes may include, but are not restricted to: acts of God or of the public enemy; acts of the Government in either its sovereign or contractual capacity; fires; floods; epidemics; quarantine restrictions; strikes; freight embargoes; and unusually severe weather; but in every case the failure to perform must be beyond the control and without the fault or negligence of the Contractor.

As a result, where terminations are used at all, they are normally terminations for convenience.

d. This brings us to the LIMITATION OF COSTS or FUNDS clauses, primarily ASPR 7-203.3 and 402.2. These clauses are similar, the salient points of which are set forth in the following three quotations:

> It is estimated that the cost to the Government for the performance of this contract will not exceed the estimated cost set forth in the Schedule, and the Contractor agrees to use his best efforts to perform the work specified in the Schedule and all obligations under this contract within such estimated cost...

Provisions for the contractor to notify the Government concerning projected overruns are also made by the clauses. Terminology differs when the contract is fully funded or incrementally funded, but the following is indicative of the language:

> ...If, at any time, the Contractor has reason to believe that the costs which he expects to incur in the performance of this contract in the next succeeding sixty (60) days, when added to all costs previously incurred, will exceed seventy-five percent (75%) of the estimated cost then set forth in the Schedule, or if, at any time, the Contractor has reason to believe that the total cost to the Government for the performance of this contract, exclusive of any fee, will be greater or substantially less than the then estimated cost hereof, the Contractor shall notify the Contracting Officer in writing to that effect, giving his revised estimate of such total cost for the performance of this contract.

The clause also includes a section on the obligations of the parties that is similar to the phraseology used in the changes clause discussed above.

> ...the Government shall not be obligated to reimburse the Contractor for costs incurred in excess of the estimated cost set forth in the Schedule, and the Contractor shall not be obligated to continue performance under the contract (including actions under the Termination clause) or otherwise to incur costs in excess of the estimated cost set forth in the Schedule, unless and until the Contracting Officer shall have notified the Contractor in writing...

The purpose of the clause is thoroughly described in *Weinschel Engineering Co., Inc.*, ASBCA No. 7046, 62 BCA 3348 as follows:

> ...This clause is designed to give the Government unilaterally an effective tool to prevent the overexpenditure of appropriated funds by establishing the estimated cost as the limit of the Government's obligation to make payment, but providing a method whereby the Government may at its election increase the estimated cost and authorize the contractor to continue performance. When the contractor complies

> with the Limitation of Cost clause, it protects the contractor fully against incurring cost for which it cannot be reimbursed, and at the same time it provides advance information to the Government, so that additional funds may be made available in ample time to prevent cessation of work, if Government officials charged with such responsibility decide that the allotment of additional funds to the project is warranted. A contractor has no right to usurp the Government's prerogative to control the expenditure of public funds by violating the Limitation of Cost clause and continuing to incur costs after the funds 'earmarked' for the project have been exhausted...

The board has generally held the Contractor to the terms of the notification requirements. In *PRD Electronics, Inc.*, ASBCA No. 7713, 62 BCA 3282, the Board strictly interpreted the clause.

> ...We do not question appellant's good faith. On the other hand while the results may be harsh we have no choice other than to enforce the contract as written. The terms of the Limitation of Cost clause are quite plain. Appellant had a duty to notify the Government when it reached the 85% figure named in the contract, and as a matter of prudent business it must have known or should have known what its actual situation was cost-wise at all times during performance.

e. Cost-plus-a-percentage-of-cost (CPPC) contracting systems are prohibited under several statutes that are not necessary to discuss here. Generally, the prohibition applies to the contract itself, or a contract provision that makes the apparent contract type a CPPC contract in fact. However, the Board has also held in *American Pipe & Steel Corp.*, ASBCA No. 4611, 60-2 BCA 2769 that certain equitable adjustment calculations

> would be subject to the justifiable suspicion that the contract had been converted into an illegal cost-plus-a-percentage-of-costs contract.

A further discussion of CPPC in the area of concern to this paper is found in paragraph 4c below.

f. To summarize the discussion on background:

(1) The Government and a contractor have entered into a contractual arrangement where the contractor promises to use his best efforts to accomplish the work required within the funds allocated by the contract. The contract provides that a fixed fee will be paid by the Government upon performance of the work.

(2) However, the contractor does not promise to accomplish the work within the funds provided. Nor does the Government promise to provide additional funds if the contractor finds during performance that more funds will be needed. In fact, the contractor cannot usually be held at fault if he does not succeed, provided the failure to perform was not his fault and was beyond his control.

(3) If during performance of the contract, the Contracting Officer changes the contract within his authority, the parties must negotiate an equitable adjustment. This agreement will include appropriate increases or decreases in cost, delivery schedule, fee, or other affected contract provisions.

2. THE PROBLEM and THE DECISION: With the underlying philosophy thus established, situations outside of normal contract performance should be discussed:

a. the contractor properly notifies the Government of an impending overrun in compliance with the Limitation of Cost or Funds clause of the contract, or

b. the contracting officer unilaterally exercises his authority and issues a change order, or

c. the parties will negotiate a change to the contract by a supplemental agreement, or

d. there is late, defective, or inappropriate Government furnished property, or

e. there are any of many other circumstances leading to the need for a change to the contract.

Depending upon the situation that exists, there are several avenues or alternates, for resolving the situation:

a. terminate for convenience. Exercising this alternative could mean that the Government no longer has a need for the effort being procured;

b. allow the contractor to continue to work and expend funds up to the cost amount provided in the Schedule. The parties must then reach an equitable agreement as provided by a paragraph of the Limitation of Cost or Funds clauses;

c. fund the overrun. This normally involves a negotiation to establish

the amount of the overrun and thus determine the amount to be funded. Deciding to follow this alternative means that the Government still wants what it originally contracted for;

d. reprogram or redirect the contract to reduce the work and the estimated total cost and fixed fee. This normally entails revision of a portion of the Government requirement, often a part of the statement of work;

e. reprogram or redirect the contract to increase the estimated total cost and fixed fee. This usually requires adding some requirement in quantity of units to be delivered, tightened delivery schedule, increased testing, etc;

f. any combination of *c* through *e*.

The terms reprogram and redirect are used interchangeably. For the sake of discussion and complete illustration of the method presented by the forms to be discussed later, proper notification of an impending overrun will be assumed. Of the alternates presented above, alternate *f* is selected. It provides the most complicated and therefore best alternate for presentation of the method and an example.

3. THE SOLUTION: The contractor properly notified the Contracting Officer that an overrun of the total estimated costs set forth in the Schedule was forecast. The Government knows the amount because the contractor is caused to provide this information by the Limitation of Cost or Funds clause. The act of funding does not take place at this point however. The Contracting Officer must first make a finding of fact as to the cause of the overrun. If he finds that the overrun was beyond the control and without the fault or negligence of the contractor, an analysis of the reasonableness of the propsed overrun costs is required. The Limitation of Cost and Funds clauses state:

> If at any time the Contractor has reason to believe that the costs which he expects to incur in the performance of this contract in the next succeeding sixty (60) days, when added to all costs previously incurred, will exceed seventy-five percent (75%) of the total amount then allotted to the contract, the Contractor shall notify the Contracting Officer in writing to that effect.

This sentence, by stating that the previously incurred costs should be added to those the contractor expects to incur, sets forth the only method that should be used.

a. I developed AFFTC Form 69, Current Contract Fiscal Status Report, to provide the data necessary to evaluate an overrun. The form, provided as Exhibit 1, is fully explained in the instructions on the reverse of the form.

CURRENT CONTRACT FISCAL STATUS REPORT (See Reverse for Instructions)							CONTRACT NUMBER		DATE PREPARED	
COST ELEMENT A	COST INCURRED TO DATE[1] B		ESTIMATE TO COMPLETE C		ESTIMATE AT COMPLETION D		CONTRACT E		VARIANCE F	
	HOURS/BASE	AMOUNT	HOURS/BASE	AMOUNT	HOURS/BASE	AMOUNT	HOURS/BASE	AMOUNT	HOURS/BASE	AMOUNT
SUB-TOTAL		$		$		$		$		$
G & A EXPENSE										
TOTAL ESTIMATED COST		$		$		$		$		$
FIXED/FEE PROFIT		N/A		N/A						
TOTAL ESTIMATED COST & FEE		$ N/A		$ N/A		$		$		$ -0-

[1] As of Date for Costs Incurred

AFFTC FORM JUL 76 69

Exhibit 1

> This analysis is to be based on the contract as currently written and should not reflect any anticipated changes to the Government's requirements. Completion of this form presents the anticipated value of the contract as written (estimate at completion) and identifies the extent of any overrun. Establishing the estimate at completion and extent of the overrun insures that any unintentional "Cost-plus-a-percentage-of-cost" calculation will be avoided when changes to the work are negotiated. Completion of this form allows the Government to make the decision whether or not, or at what level to fund the overrun.

Following the guidance set forth by the Limitation of Cost and Funds clauses discussed above, the form provides for six columns:

A. Cost Element: The contractor is to propose in DD Form 633 type format. This provides uniformity and ease of evaluation.

B. Cost Incurred to Date: These incurred costs are those costs the contractor has expended in performance of the Government's requirements. Since the contractor's accounting system must be approved by DCAA for cost reimbursement contracts, the costs presented in this column are readily verifiable by the ACO or a member of his staff.

C. Estimate to Complete: This column reflects the contractor's current estimate of the effort necessary to complete the uncompleted portion of the contract as written. The form instructions provide:

> This column presents data crucial to successful analysis and negotiation. Provide cost or pricing data in sufficient detail supporting the estimate to show that current labor, overhead, material, etc., rates and factors have been utilized, and that labor effort proposed is adequately documented. Use of current rates and factors in calculation of this estimate insures that any overrun is shown in current dollars, and that any funding action will cover the actual extent of overrun.

It is, of course, essential that this column be composed of the most current estimates available. Using any data that is less than current will result in underfunding or overfunding the overrun.

D. Estimate at Completion (sometimes also called the Revised Total Estimated Cost at Completion): This column is the summation of costs incurred to date,

plus the estimate to complete the uncompleted portion of the contract as currently written. As shown in Exhibit 1, fee really only becomes a factor at this point. Entering fee in the appropriate place in this column again puts the contractor on notice that fee is not paid on overrun, if the overrun was not caused by the Government. The Board has held that where the Government was the causative agent, an equitable fee adjustment is due.

E. Current Negotiated Contract Amount: The contractor enters the current contract cost elements and fixed fee as presently negotiated.

F. Column F: This column is the difference between column E and column D and provides in clear detail the underrun or overrun. The column instructions require that the contractor include

> narrative documentation which supports reasons for the variance including technical differences, material escalation, rate escalation, etc. This column must be supported by a DD Form 633-4. If the amount of funded overrun exceeds $100,000, a certificate will be required.

Note in the Exhibit that a zero (0) is entered for fee since this is the normal condition for fee in this column. A DD Form 633 series form and certificate of current cost or pricing data are required in order to comply with ASPR 3-807.3 (a)(ii).

A Form 69 should be used in every case to support a contractor's claim for overrun. It is the simplest, yet most complete method for obtaining the data necessary to evaluate overruns, or to ascertain the present condition of the contract.

b. To continue the discussion of the method, alternate 6 was chosen, which is a combination or occurrances: overrun, adding, and deleting effort. We have discussed overruns, recognizing that they occur and that the Government may or may not fund them. Additions and deletions of work required, accelerating or decelerating schedules, changing specifications, and others are all occurences that happen frequently. The problem revolves around the proposal of the increased or decreased costs, and the resolution of any fee increases or decreases associated with the cost. The AFFTC Form 70, Contract Change Proposal, was developed to follow the method used by the Board and to cope with the inadequacies of the DD Form 633-5 in the cost reimbursement area, which will be discussed later. It is provided in Exhibit 2. The instructions on the reverse of the form provide this explanation of its purpose:

> Completion of this form provides the basis for successful negotiation of any overrun and addition/deletion charges effecting the contract as currently written. AFFTC Form 69, Current Contract Fiscal Status Report, should be completed before this form (*the Form 70*) to present the extent of any overrun, and the estimate at completion. Negotiation of these two items, especially the estimate at completion, allows the negotiations to continue on

CONTRACT CHANGE PROPOSAL

(See Reverse for Instructions)

CONTRACT NUMBER

DATE PREPARED

COST ELEMENT A	ESTIMATE AT COMPLETION B		DELETED COST C		ADDED COST D		REVISED ESTIMATE AT COMPLETION E	CURRENT NEGOTIATED CONTRACT AMOUNT F	$ FUNDS G
	HOURS/BASE	AMOUNT	HOURS/BASE	AMOUNT	HOURS/BASE	AMOUNT			
SUB-TOTAL		$		$		$	$	$	$
G & A EXPENSE									
TOTAL ESTIMATED COST		$		$		$	$	$	$
FIXED FEE/PROFIT						TBD[1]	TBD[1]		TBD[1]
TOTAL ESTIMATED COST & FEE		$		$		$ TBD[1]	$ TBD[1]	$	$ TBD[1]

[1] To be Determined (TBD)

AFPTC FORM JUL 74 70

Exhibit 2

the additions/deletions by establishing the estimate at completion as a firm baseline.

The columns are described below:

A. Cost Element: This column is the same as discussed for the Current Contract Fiscal Status Report above.

B. Estimate at Completion: The data entered here is the same as that developed for column D of the previous from. It is what the face value of the contract would become if any overrun were funded. It is the revised estimated cost of the work originally required.

In *Modern Foods, Inc.*, ASBCA No 2090, 57-1 BCA 1229, the Board

> held that a proper equitable adjustment is the difference between what it would have reasonably cost to perform the work as originally required and what it reasonably cost to perform the work as changed.

Therefore, it is proper that this column (B) be presented first.

C. Deleted Cost: The data entered in this column is the same as that shown in the 'Net Cost to be Deleted' column of the DD Form 633-5. The instructions on the Form 70 parallel those of the 633-5, but are more explicit:

> Enter in Column C work that has been deleted, and is not yet performed. This deleted effort <u>must</u> be taken out at <u>current</u> estimated hours and rates <u>to</u> maintain continuity. Your calculation of the estimate to complete the contract as currently written on the previous form included deleted work not to be performed calculated at current rates. To now remove this work at current rates in Column C should cause no problems. Since the goal toward which negotiation of the data provided by you on AFFTC Forms 70 and 69 is a plus or minus funding action <u>in today's dollars</u>, a valid estimate using current data is essential. All deleted costs shall be based on current estimates of what the cost would have been to complete the deleted work as of the time the change was contemplated. That is, if all or a part of the work, to be deleted was in an overrun condition, your estimate must provide the overrun costs calculated at current rates.

As is noted in the instructions, it is critical that the most current data be used. This ensures that any resulting modification does not under or over-allocate funds to the procurement.

D. Added Cost: The contractor must enter costs for added work which is

not presently included in the statement of work. Documentation requirements for this column are to be treated the same as it would be in a new proposal. The data entered in this column must be the same as that shown in the 'Cost of Work Added' column of the 633-5.

E. Revised Estimate at Completion: This is the new contract amount after the required changes, and includes any funded overrun. The equitable adjustment of cost, as noted in the *Modern Foods* case above is column B minus column C plus column D, resulting in column E. This approach successfully avoids any reference to the originally negotiated costs as the Board has indicated we should do in *Jerry Fine et al.*, ASBCA No. 9101, 1964 BCA 4378.

> The total cost approach has been clearly discredited as an acceptable measure of compensation in as much as it assumes the accuracy of the original bid...

F. Column F is self explanatory, and is the Current Negotiated Contract Amount.

G. Funds: However, we still need to determine how much this equitable adjustment in cost adds or subtracts to the present contract. To accomplish this, subtract column F, the Current Negotiated Contract Amount, from column E the new contract face value, or Revised Estimate at Completion.

c. This completes the discussion of equitable adjustment with regard to cost. The method presents a quick, simple, accurate and complete format and procedure for fully discovering overruns, providing for added and deleted effort, and insuring that only the funds needed are provided or reduced as appropriate.

d. Resolution of Fee: The fixed fee may be increased or decreased depending on work accomplished. ASPR 3-405.6, previously referenced, provides for this. The Changes clauses provide for an equitable adjustment in the amount of fee to be paid. The ASBCA addresses this in numerous cases. In *H.K. Ferguson Co.*, ASBCA No. 2826, 57-1 BCA 1293, the Board said about additive changes:

> The fixed fee is the contractor's compensation for doing the work prescribed by the contract, that is, the work contemplated by the parties when the contract was negotiated and on which the fee was based. The amount of work cannot be increased materially without an adjustment of the fee...

Concerning deductive changes, it said in *Emerson Electric Co.*, ASBCA No. 15591, 72-1 BCA 9440 that

> We are inclined to the view that Item III

> represented a significant part of the total performance called for by the contract, with the result that the elimination of such work from the contract...should result in a substantial reduction in the fixed fee.

In general the Board has held this to be a consistent approach to changes. It stated this in *Roscoe Engineering Corp.*, ASBCA No. 5370, 61-2 BCA 3148:

> a...profit factor must generally be added to the contractor's costs whether the change in work is additive or deductive. This is consistent with the Board's ruling in other instances...

Relative to the base for fee calculation the Board in *Herbert, Inc.*, ASBCA No. 3283, 57-1 BCA 1319 said that

> Whatever may have been appellant's hopes and fears concerning profit and loss, the fact remains that in computing profit on the basis of cost the contracting officer was applying an established principle of accounting and we can find no justification from the available evidence in the record, as distinguished from mere allegation, for refusing to adopt it.

It should be noted that, in the *Herbert* case above, the Board used the same profit percentage as was originally negotiated in calculating the reduction. There is, however, no requirement to do so, as follows. In *Algernon Blair*, Inc., ASBCA No. 10738, 65-2 BCA 5127, the Board reiterated its general philosophy and added a proviso:

> The Board hereby reaffirms these decisions holding that the same principles used in pricing additive changes apply generally to deductive changes, giving appropriate consideration to special circumstances which would reduce the credit otherwise due the Government.

Specific examples are taken from *H.K. Ferguson Co.*, cited above:

> Having arrived at the amount of increased cost resulting from changes increasing the amount and character of the work, we now have the problem of determining the amount of adjustment in the fixed fee. The fee is usually computed

> as a percentage of the estimated cost, because it has been found from experience that the estimated cost provides a practical and satisfactory basis for arriving at a reasonable fee, although the percentage figure used depends on several factors such as the type of work and services, the dollar amount, etc.

and from *Keko Industries, Inc.*, ASBCA 5762, 60-2 BCA 2738:

> Notwithstanding appellant's assertion to the contrary, difficulty attending performance of a contractual requirement is a major consideration in the determination of the amount of profit to be allowed a contractor...

As a result of the cited cases,

1. Cost is the acceptable fee base for both additions and deletions;

2. The negotiated fee percentage is acceptable as the baseline from which to negotiate a higher or lower fee amount due to factors such as risk, difficulty, etc.

The forms provide for these conclusions. However, I do not consider that the total estimated cost amount presented by column C of Exhibit 2 is the appropriate fee base in overrun situations where the overrun is not being funded. This column, Deleted Cost, is calculated based upon today's rates, factors, and hours, and includes whatever part of the overrun included in column B is not being funded. To calculate a fee reduction on this cost will result in too much fee being deleted. It results in fee deletion based on overrun work that is not to be funded. It penalizes a contractor whose contract only requires his 'best efforts'. He has not promised successful performance, does the Government then penalize him for non-successful performance? I submit that we should not. (Please bear in mind that I am discussing increasing or decreasing the total face value amount of fee, not the fee that may or may not be paid depending upon success. I recognize that fee payment is based generally on percent of completion). What then should the fee reduction base be? It should be the amount that is included in the present negotiated face value for the deleted effort. If it is inequitable to take fee back on overrun dollars that will not be provided and were never negotiated, then it should be equitable to take it back on the dollars that <u>were</u> negotiated. In G.M. Co. *Manufacturing Inc.*, ASBCA No. 2883, 57-2 BCA 1505 the significance of cost as a base is emphasized:

> There are many factors to be considered in determing an equitable adjustment in price for a change order, but by far the most important factor is cost. When a change order involves performance of additional work,

> ordinarily the price adjustment is based on the cost of the additional materials and labor to which is added an allowance for overhead and profit...The same principles used in pricing change orders involving increased costs apply generally to the pricing of change orders which reduce the cost of performance.

The original value of this deleted work, negotiated at arms length, is the <u>only</u> reasonable measure of its value and is the only reasonable basis for fee reduction. See the *H.K. Ferguson Co.* case, quoted above. The instructions on the form require this approach:

> To avoid a penalty effect of removing fee at a higher level than that negotiated, you may enter the fee to be removed in this column based upon rates and factors originally negotiated. However, on a separate sheet, you must show how the costs were derived that the fee reduction is based upon.

4. THE EXAMPLE: Exhibits 4 and 5 provide a recent case which was successfully negotiated. An explanation of the data entered in the columns would be a near reiteration of the previous discussion. The remainder of this paragraph is a discussion of the DD Form 633-5, and the problem of fee reduction where there is an overrun, and uncompleted effort is to be deleted.

a. The first item that will be addressed is the DD Form 633-5, the primary change administration vehicle provided to administrators. I have found that this form is unacceptable for all but the most simple change problems. It is misleading at best, and dangerous at worst in complex overrun/redirection situations. The form should only be used as the primary vehicle in FFP contract modifications. Why? One significant reason is that the form presents a column entitled 'Net Cost of Change'. If this column is what is claims to be, then any negotiator or buyer should be expected to add this column to the present face value of the contract. This <u>might</u> be acceptable for a FFP contract. But, in CR or CPFF procurements this technique is asking for trouble. Exhibit 3, for example is an extract of a 633-5 completed for a recent situation. On the face of it, it appears to be acceptable. In fact it was acceptable, for the Government team evaluated the add/delete proposal, and this is the negotiation result. Exhibit 4 is the completed Current Contract Fiscal Status Report, showing a $234,638 overrun. Exhibit 5 is the completed Contract Change Proposal showing a net decrease in funding of $799,253, (Column G). You will notice that net decrease in funding of $799,253 is not quite the same as the $1,047,786 Net Cost of Change amount shown on the 633-5. One main reason for the difference is the overrun shown in Exhibit 4, column F. None of it is going to be funded. Therefore, all of it is included in the Deleted Cost column of Exhibit 5.

b. The other reason for the difference is associated with the fee deletions. Normally, fee addition is not a problem, since it is treated as a new procurement and negotiated as such. The fee deletion problem is always associated with

CONTRACT PRICING PROPOSAL (CHANGE ORDERS)

Cost Elements	Net Cost To Be Deleted	Cost Of Work Added	Net Cost Of Change
Subcon. Items	$ 686,371	$ 30,290	$ (656,081)
Material O/H	112,159	8,601	(103,558)
Interdivisional Transfers	4,528	-	(4,528)
Engr. Labor	12,245	21,633	9,388
Engr. O/H	4,677	8,262	3,585
Mfg. Labor	46,850	18,845	(28,005)
Mfg. O/H	105,521	43,418	(62,103)
Other Costs	-	12,674	12,674
Subtotals	$ 972,351	$143,723	$ (828,628)
G&A Expenses	208,370	45,865	(162,505)
Total Est. Cost	$1,180,721	$189,588	$ (991,133)
Fee	69,924	13,271	(56,653)
Total Price	$1,250,645	$202,859	$(1,047,786)

DD Form 633-5 Extract

Exhibit 3

CURRENT CONTRACT FISCAL STATUS REPORT

(See Reverse for Instructions)

CONTRACT NUMBER | DATE PREPARED

COST ELEMENT A	COST INCURRED TO DATE[1] B		ESTIMATE TO COMPLETE C		ESTIMATE AT COMPLETION D		CONTRACT E		VARIANCE F	
	HOURS/BASE	AMOUNT	HOURS/BASE	AMOUNT	HOURS/BASE	AMOUNT	HOURS/BASE	AMOUNT	HOURS/BASE	AMOUNT
S/C Items		604,179		1,165,824		1,770,003		1,458,277		(311,726)
Std Commercial		1		1,728		1,729		3,008		1,279
Material Overhead		187,196		288,967		476,163		426,815		(49,348)
Interdivisional Transfers		56,684		6,500		63,184		66,154		2,970
Engr. Labor	46,892	466,479	15,415	173,559		640,038		650,100		10,062
Engr. Overhead		180,753		66,809		247,562		248,033		471
Mfg. Labor	38,721	281,046		171,084		452,130		480,150		28,020
Mfg. Overhead		651,118		391,323		1,042,441		1,131,761		89,320
Other Costs		91,006		43,404		134,410		133,619		(791)
SUB-TOTAL		$2,518,462		$2,309,198		$4,827,660		$4,597,917		$(229,743)
G & A EXPENSE		753,468		593,387		1,346,855		1,341,960		(4,895)
TOTAL ESTIMATED COST		$3,271,930		$2,902,585		$6,174,515		$5,939,877		$(234,638)
FIXED/FEE PROFIT		N/A		N/A		351,770		351,770		- 0 -
TOTAL ESTIMATED COST & FEE		$ N/A		$ N/A		$6,526,285		$6,291,647		$(234,638)

[1] As of Date for Costs Incurred

AFFTC FORM JUL 74 69

Exhibit 4

CONTRACT CHANGE PROPOSAL

(See Reverse for Instructions)

COST ELEMENT A	ESTIMATE AT COMPLETION B		DELETED COST C		ADDED COST D		CONTRACT NUMBER		DATE PREPARED
	HOURS/BASE	AMOUNT	HOURS/BASE	AMOUNT	HOURS/BASE	AMOUNT	REVISED ESTIMATE AT COMPLETION E	CURRENT NEGOTIATED CONTRACT AMOUNT F	± FUNDS G
S/C Items		1,770,003		686,371		30,290	1,113,922	1,458,277	-344,355
Std. Commercial		1,729		-		-	1,729	3,008	- 1,279
Material Overhead		476,163		112,159		8,601	372,605	426,815	- 54,210
Interdivisional Transfers		63,184		4,528		-	58,656	66,154	- ,498
Engr. Labor		640,038		12,245		21,633	649,426	650,100	- 674
Engr. Overhead		247,562		4,677		8,262	251,147	248,033	+ 3,114
Mfg. Labor		452,130		46,850		18,845	424,125	480,150	- 56,025
Mfg. Overhead		1,042,441		105,521		43,418	980,338	1,131,761	-151,423
Other Costs		134,410				12,674	147,084	133,619	+ 13,465
SUB-TOTAL		$ 4,827,660		$ 972,351		$ 143,723	$ 3,999,032	$ 4,597,917	$ -598,885
G & A EXPENSE		1,346,859		208,370		45,865	1,184,350	1,341,960	-157,610
TOTAL ESTIMATED COST		$ 6,174,519		$ 1,180,721		$ 189,588	$ 5,183,382	$ 5,939,877	$ -756,495
FIXED FEE/PROFIT		351,770		56,029		13,271	309,012	351,770	- 42,758
TOTAL ESTIMATED COST & FEE		$ 6,526,289		$ 1,236,750		$ 202,059	$ 5,492,394	$ 6,291,647	$ -799,253

[1] To be Determined (TBD)

AFFTC FORM JUL 70

Exhibit 5

finding an acceptable fee reduction base. The instructions of the 633-5 require that the

> ..."estimated cost of all deleted work" includes (i) estimates of what the cost would have been (as of the time the change was issued) to complete deleted work not yet performed, and (ii) the cost of deleted work already performed.

In other words, the current estimated cost of the work that remains is required. It is this present cost which, if it includes an overrun, makes it unacceptable as a fee reduction base. The Net Cost to be Deleted column shown in Exhibit 3 includes this $234,638 overrun. The 633-5 instructions provide no guidance on fee reduction. If a contractor follows normal proposal practice, he will calculate his fee reduction using the negotiated percentage and the total estimated cost to be deleted. This method results in $69,924 fee reduction for deleted work. When added to the fee negotiated for added work, the result is a $56,653 fee reduction. This $56,653 is too much. It amounts to a reverse CPPC condition in that the higher the contractor calculates the costs to be deleted, the greater his fee reduction will be. It motivates contractors to underestimate in two areas:

1. The estimate to complete. The greater this estimate is beyond the funds remaining, the greater the overrun. And the greater the overrun, the less likely the Government is to fund it. And the less likely the Government is to fund the overrun, the more likely it is to negotiate a reduction in the work to be accomplished and therefore the fee to be paid. And the greater the overrun amount included in the deleted cost base, the more fee will be lost;

2. Cost of deleted work not yet performed. This is an estimate. The lower this value, the lower the fee reduction.

Of course the obvious result of this underestimating will be an underfunding of the work remaining. But the 633-5, by not providing a method for an equitable fee reduction, motivates contractor to underestimate cost to maximize the retention of the remaining fee.

c. Exhibit 5 shows a fee reduction based on the total estimated cost less the overrun amount. This $48,275 fee reduction allows $21,649 in fee to remain on the contract. This $21,649 would have been unjustifiably removed if the overrun had been included in the fee reduction base. The contractor would have been penalized that much for administrative or technical problems when this is a 'best efforts' procurement.

But would the contractor actually have proposed a reduction of $69,924? Probably not. The contractor, as this one did, would not propose any fee reduction. Or, if he did, it would be an amount much smaller than the $69,924 I show in Exhibit 3. Then what would the proposed fee reduction be based upon? Nobody really knows, except that it is the amount the contractor is willing to have deducted. And

an "equitable" reduction would have been negotiated. Based on what? Nobody knows that either, but is probably would have used the contractor's proposed reduction as a starting point.

Herein lies the CPPC danger. No one, not even the contractor, really knows what the fee reduction associated with the deleted work should be without using the proposed method. Any contractor which is serious about negotiating will attempt to cloud this aspect of the fee reduction problem. For even if fee is not the primary motivator, no contractor is willing to reduce fee unnecessarily. And the Government negotiator, under pressure to resolve the problems created by the change order or overrun as they often are, will negotiate an equitable adjustment. But my question remains. Based on what? The Board cases cited above, especially *H. K. Ferguson*, and *Herbert*, fully support cost as the reduction base. These and other cases indicate that the exact percentage may be the same as originally negotiated, or more or less depending upon complexity, risk, and other factors. It is my firm belief that the proposed percentage must be the percentage originally negotiated. For the procurement as a whole, this percentage rate was the rate found to be fair and reasonable to both parties during arms length negotiation. It must be the starting point. It will often be the ending point as well. But negotiations can then be held to increase or decrease the rate from that point depending on the facts of the situation, if necessary.

In our example it is simple to create a CPPC condition. The contractor merely has to propose, and the parties negotiate an amount less than the $48,275 in fee without explaning the circumstances making it different than the baseline fee percentage. CPPC enters into the picture at this point: When not enough fee is returned. The extra remaining fee may be considered to increase the fee rate on the work remaining over the rate originally negotiated, which I believe to be a potential CPPC system. However, there is nothing erroneous or wrong in negotiating a fee less than the baseline percentage, provided that the parties agree that the work is less complicated than that proposed, the risk on the contractors part is less than on the remainder, or some other reason that justifies a lower fee reduction and documents the basis for the equitable adjustment. It is not enough to say that any agreement is equitable in this situation. The facts must support the lesser fee reduction, or CPPC results. The only subjective aspect of this equitable fee deletion is the amount, not that one is necessary.

With regard to fee adjustments, many cost reimbursement contracts provide for payment of fee based upon percent of completion. It should be obvious that payment of fee on this basis, and removal of fee based upon the originally negotiated costs are not related. We are not dealing with terminations or with payment of fee. The fact that a contract clause may require fee to be paid on the percent of completion basis, and that the ACO may have overpaid fee normally has no bearing on deleting fee for work which is not going to remain in the contract. After deleting fee by the method presented by the forms, the Government may find that a fee overpayment has occurred, and it may be resolved at that time.

To reiterate. Failure of the negotiator to use the originally negotiated cost value of the deleted work as the fee application base is inequitable. When an overrun exists, this approach penalizes a contractor unjustly. Further, the contractor and the negotiator must use the originally negotiated percentage rate as the base for determining the proposed fee reduction. If other factors are involved, the basic fee percentage may be increased or decreased to result in an equitable adjustment. But without specific identification and negotiation of the original cost base and fee rate, the Government treads the thin ice of CPPC contracting. I would like to point out again that if CPPC exists at all, it is generally a very subtle and unintentional occurance. I became aware that the potential conditions for CPPC exist only when I did a thorough analysis of what the proposed method was telling me.

5. CONCLUSION: The proposal, analysis, and negotiation of CR and CPFF fiscal problems in DOD is relatively unsupported by formal guidance. Contractors and Government negotiators use several different methods in reaching conclusions that appear reasonable. Due to the DD Form 633-5, contractors are often forced to propose to return too much fee, and as a result often propose no reduction at all. Therefore actual fee reductions may be documented by catch words and key phrases. The original fair and reasonable fee rate, if it is used at all, is applied against a cost base that may not represent the value of the deleted work to the Government. Since the baseline cost and the fee rate are sometimes not identified and documented fully, CPPC conditions may exist and the equitable adjustment process is much more of an unknown that it needs to be. The proposed method solves these problems by

a. clearly establishing the current status of the contract and identifying any overrun;

b. clearly identifies the additions and deletions of cost against what the contract would cost to complete without changes;

c. providing for fee reductions based upon a non penalty oriented cost base and the original fee rate as equitably adjusted d

d. clearly provides for the actual funds necessary to complete the contract as changed.

My experience has shown without exception that use of the method presented by the forms clarifies and simplifies the administrator's job. Complex contractual problems can be easily and quickly resolved. Uniformity of approach and method allows administrators to become thoroughly familiar with the procedure. Negotiations can be concluded more quickly since common ground for discussion is available at the outset. Contractors can be assured of a consistent approach on the part of different Government administrators, offices, divisions, or agencies in the resolution of similar problems. Management can be assured that inadvertent and therefore untraceable mistakes are not made in critical, complex contract changes. And, it will make equitable adjustments truely equitable.

METHODOLOGY FOR DETERMINING RELATIONSHIPS BETWEEN MATERIAL PRICES AND BLS INDEXES

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NOTE: Dr. Platt's paper is not available for publication. However, this abstract gives a brief overview of his subject.

This paper will document recent research in the general field of escalation pricing techniques. Specifically addressed will be the methodology which appears most applicable to the analysis of the relationship between prices paid by an industrial contractor for raw materials and published Bureau of Labor Standards (BLS) type price indexes.

During the last decade, inflation of price levels for the US economy has reached abnormally higher levels when compared to rates experienced after WWII. Common indicators used to depict such change in price levels are indexes published by the Bureau of Labor Standards (BLS). The Consumer Price Index (CPI) and the Wholesale Price Index (WPI) are among such BLS published indexes.

In effecting negotiated type procurement of defense and aerospace items, the Federal government is often buying under contractual arrangements extending over a period of several years. Thus, in contract periods where high inflation may occur or is at least anticipated, some provision must be made for estimating total contract cost over the future years. This can be done by using labor and material factor prices which consider potential future inflation. As a logical solution to estimation of such future price increases, the Federal government has developed a technique of using selected BLS indexes or subsets thereof to serve as valid indicators for the behavior of discrete contract prices or cost groups. An inherent problem in this indexing technique is the utilization of proper BLS indexes which display an accurate portrayal of the changes in the level of prices for which they serve as indicators.

This paper documents research conducted concerning the behavior of actual raw material prices paid by a contractor when compared to published BLS indexes. A demonstrated methodology used for such comparisons is explained. The results of comparing actual prices and index data using the methodology are then presented.

The methodology described is based on simple linear regression techniques. Linear regression analysis can be conducted on the raw cost and index data, or a modified form of the raw data such as scaling, log linear, per cent change, etc. Regression results vary with the modified data format employed. Additionally, the special "no-intercept" version of linear regression can be employed to eliminate the intercept coefficient from the normal $y = a + bx$ model, thus yielding results in the $y = bx$ form. Criteria developed to evaluate the degree of relationship between prices and indexes are then explained.

Results from analysis of actual raw material prices and BLS indexes using the described methodology are recapped. Analytical results are then evaluated using the developed criteria. Finally, suitability of this methodology and criteria for various conditions and circumstances is discussed.

ESTIMATING, PRICING, AND NEGOTIATING - A NEW FRONTIER

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It is expected the new frontier in pricing will offer a little something for everyone. For those actively involved in major weapon system estimating with specialized skills in operation research, industrial engineering, accounting, price/cost analysis, financial management, auditing, production control, and contract management, the real doer involvement will be addressed in this presentation. For those with a more passing interest, the detailed discussion will be rendered into discrete issues related to past, present, and future major weapon system cost estimating. Lastly, top management should find a fresh opportunity to continue to "do something" about the two specific factors identified and associated with the accuracy of major weapon system cost.

To those familiar with MIL Standard 881 Work Breakdown Structure requirements and DODI 7000.2 with its Cost/Schedule Control System Criteria (C/SCSC), this presentation will review familiar ground. This system will be proposed, in part, for precontract application. In a similar fashion, the contractor and Government cost proposal managers will find that weapon system and contract pricing which are presently done in a summarized fashion will be proposed to be accomplished on a massive detail scale. The computer specialists will be identified with this area. Computer hardware and applications have advanced, but their use in estimating, evaluating and negotiating has been somewhat ignored in procurement research, and largely unapplied in our business activities. For management, this presentation presents improvement in two major areas:

Accuracy of cost for program decision purposes where increased accuracy of all portions of Life Cycle Cost is necessary because of the evolution of cost as an equal partner to other considerations; and

Accuracy of the cost base line for program cost control during a program.

To realize these improvements may require a DOD-wide (including contractor) examination as to how we will perform our proposal, evaluation, and negotiation efforts for the next five - ten years. More important is examination as to how we will allocate our manpower resources between the major weapon system issues of performance, schedule, and cost.

THREE FACTORS

The technique of computerized estimates for evaluating contract cost proposals has been developed at the US Army Aviation Systems Command (USAAVSCOM) in St. Louis and utilized in many Should Cost applications. This presentation draws heavily on AVSCOM's experience. Others have developed and utilized computer programs for similar applications. In fact, this was the subject of a paper presented at the second DOD Procurement Research Symposium held in 1973.[1]

The implementation of MIL Standard 881 and its systematized Work Breakdown Structure (WBS) established a framework and contractor acceptance of a cost collection system by which lower level estimates can be rolled up into the cost of major end item hardware. This led to the contractor's acceptance of a detailed lower level WBS estimating system. However, this system is used after contract award for program cost and schedule control.

The final factor discussed and integrated in this paper is the capturing of cost data for evaluation and negotiation at the lowest level of the WBS. It has been a unique effort associated with Army competitive development and design-to-cost.

THE PAST

Computer programs are not new to the contract pricing area. There have been evolving and improved computer programs for the major defense contractors or for specialized uses in the early years of this decade. Although programs have been

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[1]Captain Grady L. Jacobs, USAF; Computer Cost Models in Contract Pricing; Second DOD Procurement Research Symposium; Naval Post Graduate School; Monterey, California, P. 180 - 208.

developed and improved, we have in no way reached the place in their development where significant improvements are no longer possible. The initial programs merely compared the contractor's position in the elements of cost, such as labor, material, and overhead, with the Government's position. Later models have the capability of making complex calculations which permits the negotiation of time related considerations in the materials and the labor cost proposed by the contractor. The two tables below depict typical outputs as this development took place:

TABLE 1

EARLY MODELS
(VALUES IN MILLIONS)

COST ELEMENT	PROPOSAL	OBJECTIVE	NEGOTIATE
Materials	31	28	24
Matl Burden	4	3	2
TOTAL MATL	35	31	26
Eng Hrs	(.5)	(.3)	(.3)
Eng Dollars	3	2	2
Eng Overhead	4	3	3
Mfg Hrs	(1.8)	(1)	(1.4)
Mfg Dollars	9	5	7
Mfg Overhead	18	10	14
Other Cost	15	14	13
TOTAL COST	84	65	65
G&A	13	10	11
TOTAL	97	75	76
Profit	10	7	7
TOTAL PRICE	107	82	83

TABLE 2

MORE ADVANCED MODELS
(VALUES IN MILLIONS)

COST ELEMENT	1975 CONTR	1975 GOVT	1976 CONTR	1976 GOVT	1977 CONTR	1977 GOVT	TOTAL CONTR	TOTAL GOVT
Materials	20	20	10	8	1	-	31	28
Matl Burden	3	2	1	1	-	-	4	3
TOTAL MATL	23	22	11	9	1	-	35	31
Eng Hrs	(.3)	(.2)	(.2)	(.1)	-	-	(.5)	(.3)
Eng Dollars	2	2	1	-	-	-	3	2
Eng Overhead	3	3	1	-	-	-	4	3
Mfg Hrs	-	-	(.6)	(.3)	(1.2)	(.7)	(1.8)	(1)
Mfg Dollars	-	-	3	2	6	3	9	5
Mfg Overhead	-	-	6	4	12	6	18	10
Other Cost	-	-	5	5	10	9	15	14
TOTAL COST	28	27	27	20	29	18	84	65
G&A	4	4	4	3	5	3	13	10
TOTAL	32	31	31	23	34	21	97	75
Profit	3	3	3	2	4	2	10	7
TOTAL PRICE	35	34	34	25	38	23	107	82

PRESENT

Computers are generally recognized as providing three specialized advantages which are speed, accuracy, and the related value of being able to handle great volumes of material (capacity). It is this latter value of capacity, which is presently underutilized, that permits the development of computer programs for the specialized use in evaluation and negotiation associated with major weapon system source selections and contract award. It is largely through the USAAVSCOM Procurement and Production Directorate's effort in Should Cost that computer technology has been put to work in the arena where the final act is a signed contract. This procurement research was a systematic

evolution, with no real "Task Force" to accelerate development and test. Finally, computer programs have been developed which will faithfully produce the bottom line price with all the accompanying lower component level values for categories of cost, such as material, manufacturing labor, engineering labor, manufacturing overhead, other direct charges, G&A, and profit. Advances have been made to where the computerized programs handle large amounts of detailed/time phased data for both the contractor's position and the Government's position. This permitted isolation of the major areas of difference so that the parties, in examining the computer printouts, could more effectively communicate and concentrate their efforts on these areas.

FULLY UTILIZE TECHNOLOGY

The current USAAVSCOM models, innovated as they are today, are expected to be outdated as procurement estimating research continues and a new generation of programs is developed. These new programs will permit real time negotiation through the use of computer science. Whereas the current system requires batch processing with a certain time lag for key punching and processing of the changed input data, the program planned for development will permit entry via a terminal keyboard and negotiations utilizing a display located with the contractor and Government negotiators at the negotiating table. Such an improved computer capability provides the real time capability and approaches the type of efficiency and utilization of contractor and Government personnel which is expected to make this type of computerized evaluation and negotiation the standard technique in five - ten years.

Other computer advances will be incorporated in the evaluation and negotiation application. The computer augmented with a printout capability provides another dimension. It is expected that in a stalemate, the selected lower level details at issue will be few in number and can be selected, printed out, and more thoroughly pursued by engineers, accountants, and other analysts representing the parties involved.

It will be important to proceed with computerized application in a coordinated effort with Service/DOD and contractor personnel. One program and one data base is all that is necessary for each major contractor. This common usage will not only be efficient in the developing of the systems, but offers further advantages. A single program and a single source of data would also permit a significant amount of the negotiations to be conducted over telephone lines with both parties having display units. The day should come when preliminary negotiations will be conducted by phone and computer, with the parties having very little contact with each other, thus minimizing the cost of travel and loss of personnel for other duties while on travel status. When evaluation findings are developed, this information is fed on a real time basi to the common computer program by the auditor, price analyst, or industrial engineer. A simple notice to the negotiator of the quantified entree with statements as to why will replace the present volumes of poorly communicating proposals and reports.

It will be interesting to see exactly what human factor changes occur in the individual negotiating parties as a result of this improvement in the computer application. In the new planned program, as in other computer applications, it would seem the computer itself is a participant, along with both negotiators, as it sits patiently waiting for a human reaction to its last instant adjustment of values. It is expected that the computer would drive the two parties in the bargain to an earlier resolution of their differences.

In applications other than contract negotiation, major source selection and program approvals could be analyzed and evaluated via these terminals with the same safeguards necessary to prevent industrial espionage via computer. Cost information can then be made available to higher echelons.

This exploitation of computer science application to improve our archaic proposal, evaluation and negotiation business methods is important as cost becomes more and more an issue in major system decisions. We cannot exist in an era where cost is an equal partner with performance and schedule without improving our capability to manage cost information.

OVERCOMING INERTIA

While all the foreseeable and innovative uses will not materialize completely in the next five - ten years, there is no doubt that there will be significant progress along these roads during that time period. The only deterrent in making progress will lie in apathy and resistance to change associated with the conservatism of the cost analysis and contracting community. If a few contractor and Government managers, dedicated to the improvement in procurement through research, and others having a more passing interest, will place emphasis on computerized techniques, improvement of major weapon systems costing will come to fruition. Accuracy and timeliness of cost information, both of which can be improved through computer applications, are absolute necessities if cost is intended to be an equal partner in major weapon system decisions. The time for cost professionals to change business practice is here, just as the time has apparently come for the legal profession.[2]

When the task is at a meeting place with technology, the inertia has been overcome. Efforts were made in certain Army source selections to computerize as much of the cost information as was practicable. The significant difference in the more recent Army efforts to more fully utilize computers lies in the attempt to not only computerize the contractor's proposal in the historic elements of cost, i.e., material, manufacturing, manhours, overhead, but to also computerize the proposed cost by lower levels of the work breakdown structure. The next portion of this presentation will discuss the lower level data issue as a factor in improving cost estimating and evaluation.

TAILOR EXISTING SYSTEM

The concept for C/SCSC surveillance for cost control during a program, as identified in the Department of Defense guide, indicates that surveillance begins with contract award.[3]

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[2]Jack Bernstein, Computers Make Lawyers' Work Easier, Computers and People (May 1977) P. 25.

[3]C/SCSC Joint Surveillance Guide, Army Materiel Command Pamphlet, AMCP 715-10, et al, 1 July 1974, P. 1-2.

Presently, the contractor lays out his discrete budget portions, after contract award, and has to pass a review and system demonstration under the C/SCSC system. This base line is uncoordinated and unreconciled, except for the contract line item control, with the basic estimates of the contractor that were developed during either a source selection process or during the contract negotiation process. The reason for the absence of coordination and reconciliation in the basic budget as required by the C/SCSC system is generally the WBS, which is not present because of the current practices in proposal preparation, evaluation, and negotiation. The following two tables show cost as summarized in proposals (Table 3) and as summarized in the C/SCSC system WBS (Table 4).

TABLE 3

TYPICAL PROPOSAL SUMMARY
(VALUES IN THOUSANDS)

COST ELEMENT	PROPOSED
Materials	$10,008
Matl Burden	1,112
TOTAL MATL	$11,120
Engr Hrs	(57)
Engr Dollars	855
Engr Overhead	1,283
Mfg Hrs	(375)
Mfg Dollars	2,994
Mfg Overhead	5,988
Other Cost	5,562
TOTAL MFG COST	$27,802
G&A	4,704
TOTAL	$32,506
Profit	2,994
TOTAL PRICE	$35,500

TABLE 4

TYPICAL C/SCSC SUMMARY
(VALUES IN THOUSANDS)

WBS CODE	ELEMENT IDENTIFICATION	BASELINE DOLLARS
1.1	Air Vehicle	35,500
1.1.1	Airframe	28,621
1.1.1.1.	Fuselage	7,008
1	Nose Section	1,142
2	Mid Section	2,855
3	Aft Section	1,194
4	Main Pylon	368
5	Tail Cone	347
6	Tail Pylon	586
7	Stabilizer	440
8	Integration	76
1.1.1.2	Landing Gear	373
	Main Landing Gear	228
	Tail Landing Gear	145
1.1.1.3.	Transmission	3,304
1	Main Gear Box	2,657
2	Intermediate	68
3	Tail	189
4	Shafting	345
5	Other	45
1.1.4	Armament	71
1.1.5	Integration	4,824

NOTE: Shown are only 22 of over 60 elements thru the 5th level.

If, however, in a new frontier of cost estimating, we would develop, at the time of proposal preparation, the same lower level of detail that would be ultimately utilized for contract cost control during the program's operation, we will have started the surveillance at its true beginning. The contractors must prepare a lower level detail estimate which continues

to utilize the elements of cost, such as labor, materials, and burdens, but must also complete the matrix to include lower level of detail cost at the 5th, 6th, and 7th levels of the WBS. Results of this type of proposal, evaluation, and negotiation activity will form the base line used by the contractor in the C/SCSC demonstration. This necessitates that cost account managers participate fully in developing the estimate which becomes the budget and which is loaded into the contractor's computer system before the award is made. Table 5 is an example of the new WBS computer data. The fifth level main gearbox, the largest hardware item in the transmission WBS as shown in Table 4, is shown in detail in Table 5.

TABLE 5

MAIN GEARBOX
(VALUES IN THOUSANDS)

WBS LEVEL 5

COST ELEMENT	1977 CONTR	1977 GOVT	1978 CONTR	1978 GOVT	1979 CONTR	1979 GOVT	TOTAL CONTR	TOTAL GOVT
Materials	410	390	326	310	42	39	778	739
Matl Burden	28	28	23	22	3	3	54	53
TOTAL MATL	438	418	349	332	45	42	832	792
Eng Hrs	(4.0)	(3.3)	(3.3)	(3.3)	(3.3)	(3.3)	(10.6)	(9.9)
Eng Dollars	24	20	20	20	20	20	64	60
Eng Overhead	36	30	30	30	30	30	96	90
Mfg Hrs	(7.2)	(7.2)	(17.8)	(17.1)	(7.0)	(6.1)	(32.0)	(30.4)
Mfg Dollars	50	50	125	120	49	43	224	213
Mfg Overhead	100	100	250	240	98	86	448	426
Other Cost	93	93	232	223	91	80	416	396
TOTAL COST	741	711	1006	965	333	301	2080	1977
G&A	126	121	171	165	57	50	354	336
TOTAL	867	832	1177	1130	390	351	2434	2313
Profit	80	77	108	104	35	33	223	214
TOTAL PRICE	947	909	1285	1234	425	384	2657	2527

Thus, a continuity is developed between the values of the contractor proposal, as adjusted by the negotiation process, and the program's base line which will be used by the contractor during contract performance. For those a little more familiar with the C/SCSC system and CPR reporting, the only major reconciliation item between the base line for program cost control during contractor performance and the final evaluation and negotiation amount will normally be the contractor's management reserve. Any other difference would make it incumbent on the contractor to identify and explain fully. By implementing the lower level WBS proposal, analysis, and negotiation concept, there should be an improvement in the base line over that developed in the present postcontract period.

EARLIER AND BETTER

In looking at the implementation of C/SCSC system validations, the cost performance reports (CPR) and uniform WBSs, we have trained contractor and Government personnel to understand and accept, that for proper cost control, budgets must be formulated at the lowest level. We see that individuals are assigned responsibilities for those discrete portions of the budget that are, in fact, manageable within the human limitations of time and skill. The examination for use of lower level detail in major weapon system costing is nothing more than to advance the C/SCSC application and to develop this information, not in the postcontract period, but as a part of the original proposal preparation. It is believed that in this period of time the contractor's best effort would be put forward and his best estimates generated. It is those best estimates that should become the common base line for use by the contractor and the Government in all future activities.

Having examined computer science factors, the relationship to C/SCSC system and uniform WBS, it is appropriate to discuss the source and problem of data availability. If the contractor develops estimates at the lower levels earlier, and the computer accepts all that data, how are we going to evaluate and negotiate?

LOWER LEVEL DATA

At this point in the evolutionary process of improving estimating accuracy through the use of new estimating techniques, it is necessary that collaborating and supporting data be made available for evaluating the contractor's proposal. This data must also be at the lower level of detail to adequately satisfy this need. Immediately this area would be seized upon as being a prohibited deficiency requiring contractor and Government manpower beyond the capabilities of skill and time, thus negating the use of lower level detail for decision making and contracting purposes. However, on major weapon systems this simply cannot be the case. If contractors are truly pursuing design-to-cost and are considering, in their management decisions, that cost is an equal partner with other requirements, then this lower level of detail must be available. A recent article on design-to-cost is a good example of the lower level of design-to-cost efforts.[4]

If the data is not available to the contractor and thus available to the Government, the contractor is not performing his design-to-cost requirement by permitting cost to be a consideration, and in fact an influence, on the design of lower level component hardware. Even if prototyping or the prototyping schedule dictates that higher cost components are initially designed, this design must be recognized by the contractor, in doing design-to-cost and making cost/performance trade-off decisions, as requiring change for the production configuration. One of the outputs of an active and dedicated design-to-cost effort will include the tracking of original estimates and the actual cost of these items for all of the major cost drivers in a major weapon system. When doing either competitive or sole source prototyping, the cost community, including both the contractor's and Government's participants, must take

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[4]COL Ronald E. Philip and William P. Wood, Design-to-Cost Effective in Artillery Program, Government Executive (April 1977), P. 32.

advantage of the availability of actual costs incurred on lower level components as part of the manufacturing process for the prototype. One saving consideration is that there is a limited number of cost drivers at lower levels. For example, 80 - 85% of the utility helicopter manufacturing costs are in the following WBS items:

TABLE 6

MAJOR AIRCRAFT COST DRIVERS

Nose Section	Servos
Mod Fuselage Section	APU
Aft Fuselage (Transition)	Electrical Power System
Main Rotor Pylon	Electrical Harnesses
Tailcone	Instruments/Displays
Tail Rotor Pylon	Cabin/Cockpit Furnishing
Stabilizer	Engine Installation
Main Gear Box	Tail Rotor
Main Rotor Blades	Main Landing Gear
Main Rotor Head	Tail Landing Gear
Mechanical Flight Control Sys	Integration
Hydraulic Flight Control Sys	

It is recognized, of course, that two adjustments may be necessary. First, the prototype's design may need to be changed for production because of either the time constraints identified before or because later testing reveals the components will not meet other requirements. Second, since the prototype is generally a one of a kind manufacturing/purchase, adjustment may have to be made to the material, engineering, and manufacturing hours for the production mode. These adjustments would be for more sophisticated tooling, volume buying, optimizing the utilization of plant facilities, etc.

COLLECT DATA

It is important to point out that all through major weapon system development, the technical community has always availed itself of the opportunity to change design (critical design review), monitor the test results (including actual

witnessing of the test), and coerce the contractor to add tests or specimens when results are inconclusive. Thus, engineering, in assuring contractors meet maintainability, reliability, human factors, structure, fatigue, and a whole litany of other technical requirements has augmented the contractor's technical staff with their own experts and demanded lower level detail in support of conclusions. The cost community has always demanded more summarized cost data after the fact. If we are truly to make cost an equal partner, we must make the cost estimate of comparable quality so that in the decision making process it can truly be an equal consideration. Lower level cost data collected selectively, on a real time basis, is a requirement needed to execute expanded cost responsibilities.

EQUATE RESOURCES

To make cost an equal partner will require the same resources of time, people and management information systems long used by the technical community in developing their evaluation of the contractor's hardware. The point being made is that we cannot expect that cost is an equal partner until we are ready to establish improved cost data systems and to staff the cost evaluation organization with the number and skill level necessary to improve cost accuracy for decision purposes.

Thus far, the engineers and operations research analysts, who in their careers are specializing in major weapon system costing, have seen in this paper areas of significant interest. In the new frontier more industrial engineers skilled in specialized areas associated with the development and manufacturing of lower level component hardware will be require. More specific manufacturing knowledge in the area of components not heretofore evaluated in detail will be an absolute requirement and necessitate an enhancement in our technical evaluation skill. This issue of more and improved costing skill is vitally important if costs are to truly be an equal partner in decisions related to major weapon systems. The operations research analysts will utilize the actual component cost data to improve estimates of future aircraft or modifications to existing aircraft. The opportunity, through regression analysis on lower level detailed data, to develop a cost per pound

estimating capability is of significant interest. He sees the new frontier in cost evaluations and analysis as not being just more of the same, but will be an opportunity for innovative and inventive research with the new power level data. In one Army production contract, lower level production (not prototype) actuals are being collected by production lots in a continuing effort to advance research in this cost estimating methodology.[5]

Those readers who are in the field and who have mathematical or scientific degrees or backgrounds have been identified with this forecast of the next five - ten years. But the lowly accountant has been patiently waiting and has seen nothing for him. But the accountant and his fellow business majors will have a place, a very important place in this new frontier. His place is assured by the presence of indirect cost. The indirect cost can only be evaluated and negotiated with the skills of the price analyst, economist, business analyst, accountant, and auditor.

EVALUATE INDIRECT COST

For the most part, the discussions of the new frontier have dealt with direct cost. But if data by lower level WBS and computer science is to improve cost estimating, the accuracy of indirect cost must be improved concurrently. If indirect costs are not addressed to improve their quality, then the total cost, even at the lower levels of the WBS, cannot be expected to significantly improve.

The Pie Chart shows or depicts a generalized multi-million dollar airframe contract which segregates the direct type costs normally addressed in an evaluation and negotiation situation from the indirect costs which are concentrated on more

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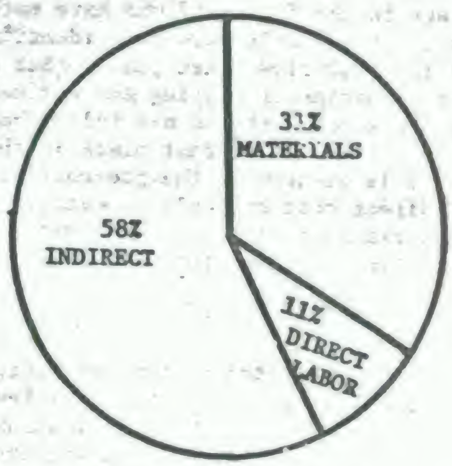
[5]CCDR Plan Attachment #13 and Exhibit A, Addendum to DI-F-6008, UH-60A Utility Transport Aircraft System, Sikorsky Aircraft and US Government (DAAJ01-77-C-0001), P. 51.

by the DCAA auditors and the ACO than by the Source Selection Evaluation or the Should Cost Team. The chart makes the important point that this indirect cost is at least as great as the direct cost and thus requires the same degree of attention.

CHART 1

REPRESENTATIVE AIRFRAME CONTRACT



In order to assure that we are able to buy the best system that our budgets can afford, in this new frontier, much more effort must be put on the proposal, evaluation, and negotiation of the indirect cost. It is significant to point out that with varying degrees of intensity, indirect costs are being managed as a part of the audit and accounting functions during contract performance. It is only within recent years that the Air Force, Navy and Army have attempted varying degrees of effort in addressing the indirect costs through overhead monitorship. These efforts have been directed at cost control during contract performance.

What has not been sufficiently emphasized is the thorough and detailed evaluation of indirect cost as part of the program estimate, contract estimate, or source selection estimate. A thorough examination of the pools making up indirect cost and the base making up the distribution of that cost must be made for each and every known contractual participant included in a program. There is a need to establish continuing responsibilities and reconciliations for cost charged direct, but estimated thru some allocation or factoring method. Real time indirect cost information is an absolute necessity in order to be in a position to have confidence in the cost information sufficient to permit it (the cost) to be a competing equal partner with the offerings of the technical community. This paper does not propose to address the detail changes necessary to improve the accuracy of indirect cost. That topic is worthy of a separate paper dealing only with indirect estimating, evaluating and control.

Is the new frontier going to be involved more and more in the contractor's business through a closer look at accounting structure which is generating the indirect cost? It must be. If half of the cost accumulated by the major weapon system is from these indirect accounts, then we have no less a responsibility to thoroughly pursue these business costs than the responsibility we shoulder when we evaluate and negotiate a bill of material cost and the engineering and manufacturing labor cost. These business costs are so called in this paper because only the business majors, the accountant, the auditor, the financial analyst, and the economist offer the skills necessary to perform the thorough review and arrive at more accurate estimates in evaluation and negotiation of indirect costs. If contractors do not establish systems to better assign responsibilities and accountabilities for business cost, the new frontier will see more and more Government analysts involved in more detailed evaluation and analysis of projected indirect cost.

OPERATING AND SUPPORT (O&S) COST

By capitalizing on the availability of more accurate lower level cost data, systems entering production can be selected based on improved O&S cost information. This new methodology attacks the weakness in the accuracy of hardware cost, thus it improves that portion of O&S cost estimates that can be identified for improvement by the cost analysis community. Most of the other shortcomings in cost accuracy are traceable to the optimism of the contractor and the Government in assessing technical requirements. For a long time the cost analyst has taken the brunt of criticism for cost growth, when performance growth was the heart of the problem. Replenishment spares are the portion of O&S cost which can be improved in cost accuracy through the use of lower level detail estimates and evaluation via the computer. Although the replenishment spares are only 16% of the O&S cost of a generic utility helicopter, they are one of the large cost items and are possibly the most discriminatory between competing systems or configurations within a define specification. The balance of the cost is largely direct and indirect people cost, and except for direct maintenance, resist discrimination between systems competing for the same requirement. The lower level detail improves the accuracy of the hardware portion of O&S cost since it improves the cost estimate of new replacement parts, repair of parts and overhaul of parts. Therefore, computerized WBS lower level data estimates will improve the O&S as well as the production cost estimate.

COMPONENT DOLLAR/POUND NOW

Systems entering development can benefit from the new methodology. Noncontract estimates for future systems or modification to existing systems can be developed using operations research techniques. By capturing cost at a lower level of detail, it becomes possible to compare cost and some related forecasting parameters through the use of regression analysis. With several systems collecting costs and weight, the next five to ten years would permit

the development of cost per pound estimating at the component level. Cost per pound has been identified only because weight, at least in the forecasting of cost for helicopters, has been the single most reliable parameter.[6] This would be a valuable tool to use as older systems are considered for modification involving some redesign. Cost per pound forecasting of that functional component would be still another estimating tool within the repertoire of the cost analyst for use in the decision making process. Currently, the UTTAS program is collecting both the cost and correspondence weights of some selected components as a first step in establishing a data base at the component level.

BENEFITS

The benefits from this evolving technique can be summarized in several specific categories associated with major weapon systems. First, the quality of the estimate for the instant contract and any options is improved over historic methods. While increased quality is not an inherent value of lower level detail where both contractor and Government technical people are more presonally knowledgeable of the hardware enhances the opportunity to develop an accurate cost. As the proposal is evaluated and subsequently negotiated, the quality of the estimate is improved as the interplay of the experts is introduced and resolutions and conclusions are developed with respect to differences.

Second, once the contract is signed, this detailed documentation becomes the detailed base line for the contract value. Changes to the contract, and particularly changes to the hardware, become easier to estimate accurately. By isolating an item such as the main gear box, the change to that component's gear can be more accurately costed. Both the contractor and the Government are better able to isolate the pool of costs involved in a change and evaluate and negotiate the adjustment to that discrete pool of cost. Both the contractor and the Government should be in a better position to evaluate engineering changes to hardware, both before they are contractually approved and when they become a bilateral adjustment in settlement of a contract change order.

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[6] Stanard, G. Norman, Parametric Life Cycle Cost Model for Army Helicopters, Proceedings Tenth Annual Department of Defense Cost Analysis Symposium, hosted by the Comptroller of the Army, Airlie House Conference Center, Airlie, Virginia, P. 72.

The third area even precedes activities associated with a contractual change. This is the area wherein the Government makes a decision based on performances or logistics versus cost. In reviewing a hardware change, accurate cost data, available at this point in time, will permit cost considerations to be an equal partner with other parameters. As cost becomes a more and more important consideration in the decision process, accurate costs must be present at more and more locations along the path of both contractual and program progress. When requirements are considered to be changed by engineering, product assurance or the user, cost estimates of quality must be immediately available for the cost trade-off decision. With the availability of cost data will come an awareness of cost consideration on the part of the technical community. Cost can become part of this trade-off analysis rather than be treated as an adversary.

ACCEPTANCE, COORDINATION AND RESOURCES

What are the current limitations preventing full implementation of this lower level estimating technique? The limitations lie in only three areas. First, more and more contractors must be encouraged to accept the innovative technique and develop computerized programs peculiar to their accounting and estimating systems. They must familiarize their personnel with the financial policy that estimates will be generated at the lower level of detail and such estimates will be fed, in some suitable format, into the computer for higher level summation. They must recognize Government access to that data on a real time basis and be prepared to consider Government evaluating input data to their programs on a concurrent real time basis.

Coordination is the second area thwarting accelerated application of the technique. Coordination will be required more for the Government and contractor negotiators and financial managers than any other group involved in the cost estimating and analysis. Contractor estimators are already somewhat familiar with the development of estimates by components; however, often these estimates have lost their individual identify in the final proposal submission. Similarly, the Government engineers and the audit position are often obscured in the Government evaluation position. The best estimate must be entered; or if adjustments are made, they must be with full knowledge and understanding of the estimators and evaluators.

Finally, both the contractor and the Government must identify sufficient people resources and raise the skill level of these people to permit cost accuracy that is in keeping with its present equal status to performance and schedules. The days when organizations operate with hundreds of engineers and a few cost practitioners should not be permitted to continue in the new frontier. The same imbalance mixture of professional personnel will not allow the new frontier to achieve any significant improvement even if we try superhumanly to make cost an equal partner.

Not only must the allocation of resources be reexamined, but the cost estimating and control responsibilities should be reviewed for the appropriateness of the organizational location. Presently major weapon system cost responsibilities are often part of the contractor and Government comptroller function.

Without going into great depth since each organization would need to be reexamined based on its own structure, it can be generally said to be mostly involved with accounting and finance and their related decisions and reports. Within that organization the major weapon system cost responsibility is a minority in the total manpower picture.

The Government at the "doer" level generally can be stated as having the exact same situation. The comptroller function at major subordinate commands devotes the majority of resources to other than major weapon system estimates. Within that organization the major weapon system cost responsibility is a minority in the total manpower.

One solution, which is a mere application of the C/SCSC "Earlier and Better" is to centralize the major weapon system cost responsibility in the procurement organization where the significant spending of program funds starts and finishes as part of the contractual arrangements. The new frontier should consider assigning program cost control responsibilities from the time of initial estimate at the start of the life cycle of major system acquisitions to the procurement executive in both the contractor and Government organization. The procurement contracts are the source of cost data and the production skills are the sanitizers of that data.

This view of the new frontier offers no compelling evidence that there is a narrow path to follow, but envisions there is a broad avenue for progress.

PROCUREMENT RESEARCH HISTORY, PROGRESS AND OPPORTUNITIES

MANAGERIAL OPPORTUNITIES AND LIMITATIONS FOR THE USE OF PROCUREMENT RESEARCH

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RELATIONSHIP OF SUBJECT TO THEME

The translation process as described by General Sharp is primarily a function of management, supported by research and operational elements. For the next few minutes I'd like to suggest some opportunities for performing this function and examine some limitations or barriers we need to be on guard for. I will cite actual experience where appropriate.

CHANGING SOURCE OF RESEARCH PROJECT GENERATION

Up until not too many years ago, many research projects in governmental and industrial laboratories, think tanks, and institutes were generated by the researchers themselves. Research projects were developed and conducted in isolation from the managerial and operational environments in which its results were expected to be ultimately used. If a project was exceptionally successful or caught management's fancy, it might find its way into the working world; but, too often the results were too modest to risk operational experimentation or were expressed in forms not usable to managers and operations.

CHANGING SOURCE OF RESEARCH PROJECT GENERATION

Traditional Picture of Ivory Tower

Research Organizations and Management/Operations Elements Moving Toward Symbiotic Relationships

Relationship Needed to Promote Long-Run Efficiency and Short-Run Survival

While this condition prevails to some extent today, the relationship appears to be changing substantially.

The relationship between research organizations and their counterparts in operations and management is moving toward an integral cooperative, even symbiotic, arrangement. While many worthwhile research projects and questions still originate in the research units themselves, jointly developed projects and management-scopes projects are on the increase. Collaboration in development and testing of research concepts, including procurement, is useful not only to promote efficiency in the long run, but is essential to sustain a research capability in times of tight budgets - in the short run.

A number of reasons exist for this increased interest by non-researchers in research goals, processes, and the projects themselves.

REASONS BEHIND NON-RESEARCHER INTEREST IN
RESEARCH GOALS, PROCESSES, AND PRODUCTS

$ the research investment may be substantial or the cost/risk of implementation may be large

The "glamour" of having a "research based" organization

Managerial exposure to research tools and methods in courses and meetings

Observed success/payoff of completed research projects

Increased awareness by management of utility and organizational survival potential of appropriately applied research

Variations in the structure of research efforts within organizations tend to promote interest across functional lines. Research responsibility may be solely in the hands of a specific group of scientists and engineers or it may be dispersed throughout the organization; or combination of both may prevail. The maintenance of equilibrium between diffusion and concentration of research responsibility and capability is one of the most important research management questions faced today. It is, in fact, the underlying theme of this year's symposium.

OPPORTUNITIES FOR STIMULATING USE OF PROCUREMENT RESEARCH

Mostly mundane, but bear identifying and reexamining. Traditional methods include publication of reports, briefings, symposia and occasional reference in classroom situations As mentioned earlier by General Sharp, two potentially powerful approaches are to put operators on full-time research teams and assign full-time researchers to implement lab tested innovations.

A fairly common practice is to have high level managers sit on research organization boards of directors, but I submit of even greater potential is to have research directors sit on operational policy boards. For example, I attend the Army Materiel Development and Readiness Command's Procurement and Production Directors' meeting held several times a year. Here I not only present major research efforts of potential use to the commands, but use the discussions as a basis for developing and guiding new projects.

OPPORTUNITIES FOR STIMULATING USE

. Traditional: Publications, Briefings, Symposia, Courses

Use of Researchers in Management

Use of Managers/Operators in Research

Place Research Managers on Management Boards

Develop Internal/External Research Communications Network

Establish and make use of a research communication network. For convenience I'll break this "Network" into two subsets, the internal research communications environment and the external.

INTERNAL COMMUNICATIONS

Ironically, internal research communications present more problems than external. Competition among researchers and between departments prevails. We still have distrust and jealousy. Accepted divisions of tasks and responsibilities limits information flow within departments. The longer ranges objectives of the research element versus the relatively shorter ones of other elements are often in conflict.

One approach to improving internal communication is to name one person each from research, policy, and field operations to each major research project whose job it is to disseminate information throughout the organization about the projects aims and schedule, in addition to providing guidance and logistical support to the project. We try to do this on major projects by having a study advisory group composed of such a mix. In one case it enabled us to abort a low payoff project early, and in another, we learned two important objectives that would have escaped.

A newsletter or periodical of organization - wide appeal is a better place to keep management and operations informed of research events. Research has shown greater acceptability of more widely based publications and greater readability.

Establishment of project officers or contact points in field organizations who act as surrogate researchers as well as emissaries and communicators have proven to be an effective channel of rapid information processing which can also provide feedback. In each of our commodity commands, we have alternate project officers, by name, who line up data, gain support, explain objectives, and provide critical feedback. Some of them are here at this symposium. In the early stages, this is one of the most important resources available. I commend it to Dan Strayer and Bob Judson.

Inclusion of a research session or presentation on the agenda of the major staff or directors' meeting is needed to demonstrate top management support and keep abreast of research which may need barriers broken down to be effectively implemented.

Internal "murder boards," where outsiders are brought in to observe the objectivity and participate are extremely useful if the organization is open enough to permit it. Not only will this type of confrontation catch errors or anticipate problems, but will in a dynamic way stimulate other researchers and managers attention to related concepts in their own projects.

INTERNAL RESEARCH COMMUNICATIONS

More problems than external: Competition, accepted division of responsibility; long run vs. short run objectives

Name one or more persons from research, policy, and field operations for each major project

Organization-wide newsletter, periodical

Field contact points - designated/dedicated

Inclusion of research activity on agenda of board of directors meeting

Internal "murder boards" with outsiders

EXTERNAL COMMUNICATIONS

This is a more highly institutionalized area, where a great deal more money is spent and the relative value of results questionable.

The use of information exchange abstracts such as the Defense Documentation Center and the Defense Logistics Studies Information Exchange, research guides such as PRG 1 and 2, external newsletters and other publications, and symposia like this one do a lot for keeping many informed about what research is going on and what has been done. They are necessary media, but they seldom afford enough treatment of the research effort and implications to aid the "translating into action" process. And, since they may be quite costly, some of these resources may be better spent promoting the internal communications network.

The "scanning" or receiving function of a research organization's external communications network is probably its most critical feature. The design and use of procedures to search, screen, and relate to ongoing research projects and research plans is essential to the efficient use of resources. This effort is in addition to the initial bibliographical and other preliminary checks made by the research team. It must be ongoing, particularly on longer range projects. Experience has shown a tendency on the part of researchers, and managers alike to check carefully at the outset, but then to neglect the scanning process as the project moves on. It may be necessary to have someone other than the principal investigator maintain surveillance, for the tendency to ignore the external environment during analysis appears natural and widely prevalent.

EXTERNAL RESEARCH COMMUNICATIONS

More Institutionalized - Cost but Value Not Demonstrated

Information Exchanges, Documentation Centers, Research Guides, External Newsletters, and other Publications, Symposia

Traditional Communication Media Necessary, But Costly - Same $ May Be More Profitable Spent on Internal Communication

"Scanning" Most Critical Aspect of External Communication - Researchers Tend to Ignore Developments After Initial Checks

RELATIONSHIP OF PURSUING OPPORTUNITIES TO PROJECT SUCCESS

To evaluate the prescriptive remarks above, I selected a number of research areas where APRO had conducted projects and divided them into relatively successful - by standards of implementation and use - and not so successful. This is risky, I know, and could offend some people, including my own shop; so please bear with me. I'm not denigrating the efforts, but merely trying to show that it takes aggressive efforts to make the translation process successful. I won't go into why I put each project in a category, but will just cite a few things we did and didn't do. In some cases, we were not able to do what might have aided the translation process due to resource limitations or lack of support.

RELATIVE SUCCESS (Opportunities taken advantage of)	RELATIVE FAILURE (Opportunities Lost)
Should Cost	Life Cycle Costing
Independent Government Cost Estimates	Contractor Performance Evaluation (CPE)
Services Contracting	Design to Unit Production Cost
RFP Improvement	Warranties Usage
CATVA	Decision Criteria for CITA
Negotiating IR&D Costs	
Quality Improvement Program for Procurement Instruments	

LIMITATIONS

The limitations on using procurement research are far more numerous than the opportunities. They include intrinsic and extrinsic factors. The intrinsic are associated with the research itself - quality, appropriateness, timeliness, practicality, cost of implementation. The extrinsic consist of legal and policy constraints, technology base barriers, organizational metabolism - or lack of it, and failures of managerial nerve to mention just a few. We, the researchers and managers can do much to overcome the intrinsic limitations, for they normally involve priorities of application in the short run. But the extrinsic are basically long run problems and must await solutions developed on a macro scale over a considerable period of time. My experience has been that we talk too much about the barriers and limitations when it comes to implementing procurement research. A little more time spent on steadily plying the opportunities may make some of the limitations disappear. Before leaving this subject we should all remember one thing - how to tell the difference between research that cannot be implemented because of external limitations and research which should not be because of instrinsic limitations. If the research cannot be implemented for extrinsic reasons, beyond the control of both research and management, the research itself should not be falsely labelled. It may in fact represent the identification of a basic root problem. While this should normally have been anticipated in the research planning, better later than never. If, on the other hand, the implementability of the research is limited by its quality or our management of the results, we must recognize this for what it is and take appropriate action.

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LIMITATIONS

INTRINSIC	EXTRINSIC
Quality	Legal Barriers
Appropriateness	Policy Constraints
Timeliness	Organizational Metabolism
Practicality	Failure of Managerial Nerve
Cost of Implementation	

SUMMARY

In this symposium, I hope we will stress the pursuit of opportunities as our objective and recognize limitations as temporary constraints which we will seek to alleviate. I don't mean stress all success stories, but to look at failures as lost opportunities which can be regained. In closing, I'd like to pose several questions which we can discuss at this session and throughout the symposium. They may provide stimulus for continuing enquiries throughout the year.

What methods of stimulating increased used of procurement research are we missing?

Is the practice of semi-annual or quarterly sittings of boards of directors to procurement research organizations effective?

Can research managers and researchers make meaningful contributions to top level policy group meetings? What are the practical drawbacks? What can we do about them?

Does the traditional process of publishing research results in scholarly form actually inhibit their implementation? If so, what alternative means could be used to gain usage and still distribute the methodology and results to others?

How can the priority of research projects be determined in situations where procurement managers and researchers collaborate on the selection of projects?

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A PROPOSED DEFINITION AND TAXONOMY FOR PROCUREMENT RESEARCH IN THE DOD: A PROGRESS REPORT

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INTRODUCTION

Extensive research has been accomplished in the name of procurement research over the past few years but no definitive, delimited concept has evolved as to what constitutes procurement research (12). A review of the early Department of Defense (DOD) Procurement Symposia "Proceedings" indicated that professionals in the field of procurement called for a definition of the term "Procurement Research" as well as the classification of its characteristics into a model to provide more efficient use of resources. Therefore, the need exists to clearly define procurement research and to classify its characteristics into a usable conceptual model.

The Federal Government spends billions of dollars each year for the procurement of the equipment, services, supplies, and personnel required for the operation of the DOD. As a consequence of the magnitude of these outlays, repeated cost, schedule, and performance problems, and increased general public awareness, the DOD procurement (acquisition) process has come under serious criticism in recent years (3:2-4).

Research has been viewed by many in the field as a key to alleviating both existing and future procurement problems (2:1). Senator Stennis, Chairman of the Senate Committee on Armed Services, and Congressman Price, Chairman of the House Committee on Armed Services, reiterated this widely held belief in a joint letter to former Defense Secretary Schlesinger:

> We recognize the value and importance of procurement research as a means of improving the procurement process -- one of the most crucial tasks in Government (8).

Even though there is a general consensus as to the importance and possible impact of research on the procurement process, procurement research as a discipline has not been clearly defined in existing literature and practice. Also, there is little agreement among the agencies performing this research as to what constitutes research (1:2). There have been several indications as to a possible scope for procurement research; for example, J. M. Malloy, then Deputy Assistant Secretary of Defense for Procurement, described procurement research as essentially "a systematic approach" that follows the scientific method (7:215). However, there has not been a concerted effort to adequately describe what should be included.

The result has been that research efforts are categorized as both tentative and diffuse (8:4). Robert Judson, then Deputy Director of Commission Studies, Commission on Government Procurement (COGP), stated that procurement research's

> . . . first order of priority . . . is to construct . . . a model so that we can share a consensus on procurement problems, . . . a comprehensive studious critical conceptual model for the acquisition process that will give us insights we do not now possess that will help us identify what we don't know (5:93).

The importance of procurement research and the necessity of defining its role in government acquisition was reaffirmed in an interview with Robert F. Trimble, Assistant Administrator, Office of Federal Procurement Policy (OFPP) for Contract Administration. He discussed procurement research as follows:

> I've long had an interest in procurement research. I think that it (an attempt to define and classify procurement research) is one that is particularly important because I have seen a considerable amount of confusion regarding what constitutes procurement research. I believe that this matter needs to be clarified so that we can more efficiently utilize the manpower resources that we have in this particular area (12).

BACKGROUND

In the past specific areas in procurement research have not been clearly delimited; thus, a historical background must concentrate on the procurement organizations that have developed during the past twenty-five years. The evolution of procurement research has been characterized by changes in organization and procedures. Research, per se, has not been emphasized; rather, the emphasis has been on the changes in DOD and Air Force procurement organization which resulted from the need for better procurement methods. The lack of a clear definition of just what procurement research includes has made this approach necessary.

In the 1950's various attempts were made to save money through reorganizing and centralizing purchases of common items. The inertia of old techniques was slow to yield to change; moreover, each military service was "isolated" from the others as far as procurement methods. In the 1960's, some efforts were made to exchange procurement information and to evaluate decision-making during the acquisition process. New approaches were being utilized to improve the management information flow. In the 1970's many changes occurred in the formal acquisition process. After many long

years of inefficiency and redundancy, the national procurement policy, education, and research are becoming centralized and coordinated under the FPI.

Mr. Robert Judson, then Deputy Director, Commission Studies, COGP, in an address to the second DOD Procurement Symposium in 1973 made a challenge to the procurement profession. He said:

> You, gentlemen, have a golden opportunity to redirect procurement research to achieve new goals of excellence. First let's do our research on the problems of research before we lose the chance to make procurement what we want it to be (5:99).

This challenge was re-emphasized by Dr. John J. Bennett, then Acting Assistant Secretary of Defense (Installations and Logistics) in the Defense Management Journal, July 1975:

> Procurement research is not yet a household phrase in the Department of Defense . . . . It needs a great deal of attention from management and those people actually engaged in procurement projects (2:1).

In summary, the important events in the evolution of procurement research start with the Second Hoover Commission in 1953 and continue up to the present time. Key events in procurement reorganization in the 1960's include the reorganization of Air Force Systems Command and Air Force Logistics Command, the Hershey Procurement Pricing Conference, the establishment of the Army Procurement Research Office, and the Commission on Government Procurement. The significant events (thus far) during the 1970's include the five DOD Procurement Symposia, the establishment of the Air Force Business Research Management Center, the addition of Graduate Procurement curricula to the Air Force Institute of Technology, School of Systems and Logistics, and to the Naval Postgraduate School, the establishment of the Office of Federal Procurement Policy, and the founding of the Federal Procurement Institute.

OBJECTIVES

The following research objectives are being pursued in this study:

1. To define procurement research so that a common foundation can be used when discussing this subject.

2. To classify procurement research efforts and functions into various areas and to identify those areas that are most frequently investigated.

3. From these classifications, to suggest a detailed algorithm which can be used for deciding whether an effort is procurement research or not.

METHODOLOGY

A literature review was initiated. It disclosed an increasing interest in the area of procurement research and in defining procurement research, but no suggestions have been made as to how this specific area of research should be defined or how it should be classified from a taxonomical standpoint. Content analysis provided a subjective technique for grouping various procurement efforts: by division of scientific study, by breadth of application, by degree of control, by level of outcome, by level of effort,* and by placement in the acquisition and procurement processes. Through a system of summarizing and categorizing, these various groups can be used to suggest a definition for procurement research.

The research design was divided into five areas:

1. Classifying procurement research efforts and functions into categories and sub-categories.

2. Identifying the areas of procurement research that were most frequently investigated.

3. Defining procurement research in terms of characteristics which were evidenced in the study.

4. Suggesting a taxonomy of procurement research.

5. Designing an algorithm to use in deciding whether an effort is procurement research or not.

The first three areas of the research design were planned to answer the first and second research objectives. The fourth design area was planned to answer the second and third objectives and the fifth design area was planned to answer the third objective.

The first design area was planned to identify specific scientific and research characteristics of procurement research as evidenced in the "Proceedings." Through content analysis, the articles of the symposia "Proceedings" have been classified into various categories and sub-categories of characteristics. These scientific and research characteristics have been correlated with areas of the procurement and acquisition processes.

To satisfy the first and second objectives, the methodological approach of semantic content analysis was adopted. From the universe of research, the population called procurement research was chosen. This population was further narrowed to the sub-population of procurement research as reported in the "Proceedings" of the five DOD Procurement Research Symposia. The analysis consisted of a census of the total sub-population of articles in these "Proceedings."

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*These categories were adopted from the Helmstadter taxonomy and the Strayer - Lockwood taxonomy. See references 4 and 11 for further discussion.

To validate the coding, a pilot study was accomplished. To enhance the reliability of the research effort, a "target" reliability percentage of 90% was achieved during the pilot study. Additionally, during the analysis, random samples of articles coded by one researcher were recoded by a second researcher to insure consistent and standard results.

After coding the data for each "Proceedings," a relative frequency count of occurrences under each digit code was tabulated. Each digit in the seven-digit code represented a category of science, research, the acquisition process, or the procurement process. The first digit was coded to show the division of science used in the research. The second digit was coded to show the breadth of application of the research techniques used. The third digit was coded to identify the amount of control used by the researcher and where the research was conducted. The fourth digit was coded to determine the level of outcome of the research effort; what could be said about the area studied, did it describe a situation, or could a model be developed to predict future events? The fifth digit was coded to indicate the level of effort used in the research; i.e., the amount of time and depth of effort necessary to accomplish the research. The sixth and seventh digits were coded to indicate the phases of the acquisition and procurement processes with which the research was concerned.

In the second design area, the results of the content analysis were combined into relative frequency distributions. Each sub-category was analyzed to determine those areas of procurement research which were most frequently investigated and which characteristics were most prevalent in the population.

The third research design area, defining procurement research in terms of characteristics evidenced in the study is being addressed at the current time. The characteristics of research and science derived from content analysis were combined with information obtained from literature reviews and personal interviews to develop a tentative conceptual definition of procurement research.

The fourth area of research design was planned to classify procurement research efforts into various areas, as stated in the second objective, and to suggest a detailed procurement taxonomy. Information for this area was gathered from existing literature and personal interviews (see Appendix 1).

The last area of research design was planned to determine whether an effort is procurement research by comparison to a designed algorithm. The algorithm would be derived from the taxonomy suggested from the fourth area of research design.

TENTATIVE FINDINGS

Though the research effort is not yet complete, initial data from the content analysis of the "Proceedings" have been tabulated, and an initial taxonomy has been developed. A tentative algorithm is currently being designed. The results of the content analysis, which are listed in Table 1, showed the following primary areas of emphasis as related to the selected criteria.

TABLE 1 - SUMMARY OF FINDINGS

1. Division of Science: Social (45.05%)

   Abstract/Social combined (45.75%)

2. Breadth of Application: Applied (61.26)
3. Degree of Control: Library (52.25%)
4. Level of Outcome: Descriptive (55.86%)
5. Level of Effort: Professional Paper/Research Monograph (68.46%)
6. Phase of the Acquisition Process:

   More Than One Phase (37.83%)

   Not Concerned with the Acquisition Process (46.85%)

7. Phase of the Procurement Process

   Pre-award (45.95%)

   More Than One Phase (33.33%)

As corollary information to the content analysis, the researchers noted the source of each article. Cf the one hundred eleven (111) articles, the source distribution is recorded in Table 2.

TABLE 2 - ARTICLE SOURCE DISTRIBUTION

AGENCY	NUMBER	PERCENTAGE
DOD	8	7.21%
AIR FORCE	38	34.23%
ARMY	19	17.12%
NAVY	14	12.61%
NON-DOD		
Government	11	9.91%
Private Business/ Universities	21	18.92%

The initial taxonomy was divided into five levels of procurement research. Each level subdivided the previous level into more specific areas where procurement research can be identified.

TENTATIVE CONCLUSIONS

Current progress in the research effort has suggested tentative answers to the research objectives. The results of the research to date suggest the following definition of procurement research:

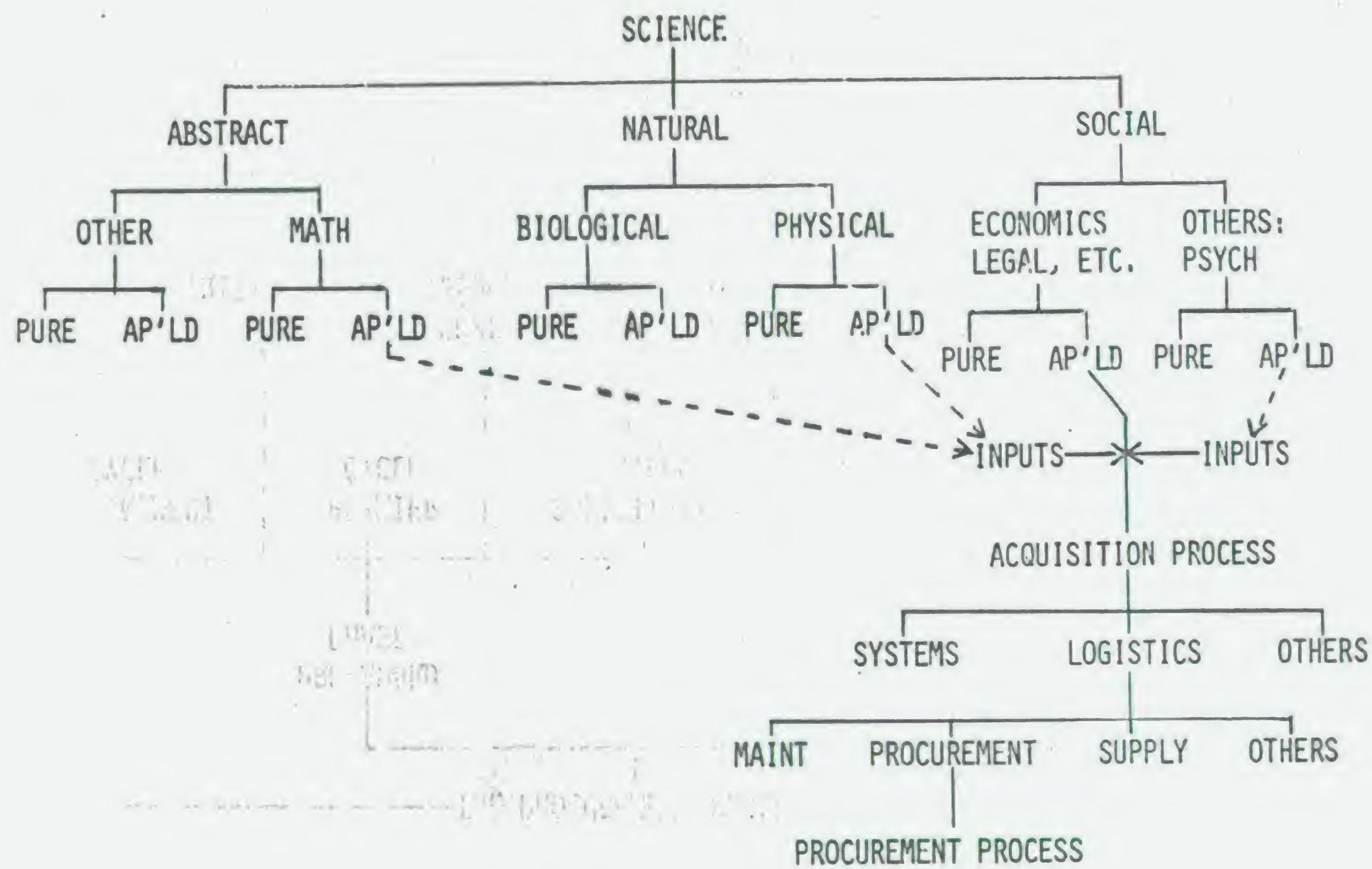
> Procurement Research (and Acquisition Research) is an applied science using the characteristics of the social sciences in combination with abstract or mathematical sciences to solve procurement problems. It tends to rely heavily on the use of previously gathered data (library research) to seek solutions to problems, equally dividing its efforts between the acquisition and procurement processes, with major emphasis in the procurement process in the pre-award phase in an effort to identify cost-related problems in the procurement of either major weapon systems or non-weapon systems.

The results of the content analysis are limited to the actual sub-population itself, but the sub-population of the "Proceedings" represents an important cross-section of recent DOD procurement research experience. Information derived from the analysis of this sub-population can suggest important characteristics and relationships of other procurement research efforts.

The areas of emphasis in the procurement research of the "Proceedings" were identified in the content analysis. Procurement research was characterized as a social science with abstract science combined more often than not. Efforts were primarily applied to solving problems. The research was primarily done through a selected aggregation of information (library) and the level of outcome was descriptive. In the sub-population, the level of effort was primarily a professional paper/research monograph. The relationship of procurement research with the acquisition process showed that efforts generally involved more than one phase of the acquisition process or were not concerned with the acquisition process at all. Emphasis in the procurement process was primarily in the pre-award phase with many articles dealing with more than one phase.

The definition of procurement research and the classification of the characteristics of procurement research were combined with the information from the interviews (6, 10, 13) and the literature review to develop the present taxonomy. The emphasis for the taxonomy has been to cover all possible areas of procurement research as suggested by various information sources. A tentative taxonomy which has been developed by the researchers is reflected in Appendix 1.

The research effort will be adjusted as the researchers discover new information that impacts on the definition, the taxonomy, or the algorithm. Current plans include a more detailed study of the results of the content analysis to show possible shifts in areas of interest within the acquisition and procurement processes; the development of a sixth level (where possible) in the taxonomy, such as COST DESIGN which is on the fifth level under COST/PRICE ANALYSIS under the SOLICITATION/EVALUATION Cycle in the PRE-AWARD PHASE. The next level (sixth) under COST DESIGN would be areas such as Life Cycle Costing, Design to Cost. Lastly, refinement to improve accuracy and reliability of all areas of the research effort will be accomplished.


SCIENCE
ABSTRACT
NATURAL
SOCIAL
OTHER
MATH
BIOLOGICAL
PHYSICAL
ECONOMICS
LEGAL, ETC.
OTHERS:
PSYCH
PURE
AP'LD
PURE
AP'LD
PURE
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PURE
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AP'LD
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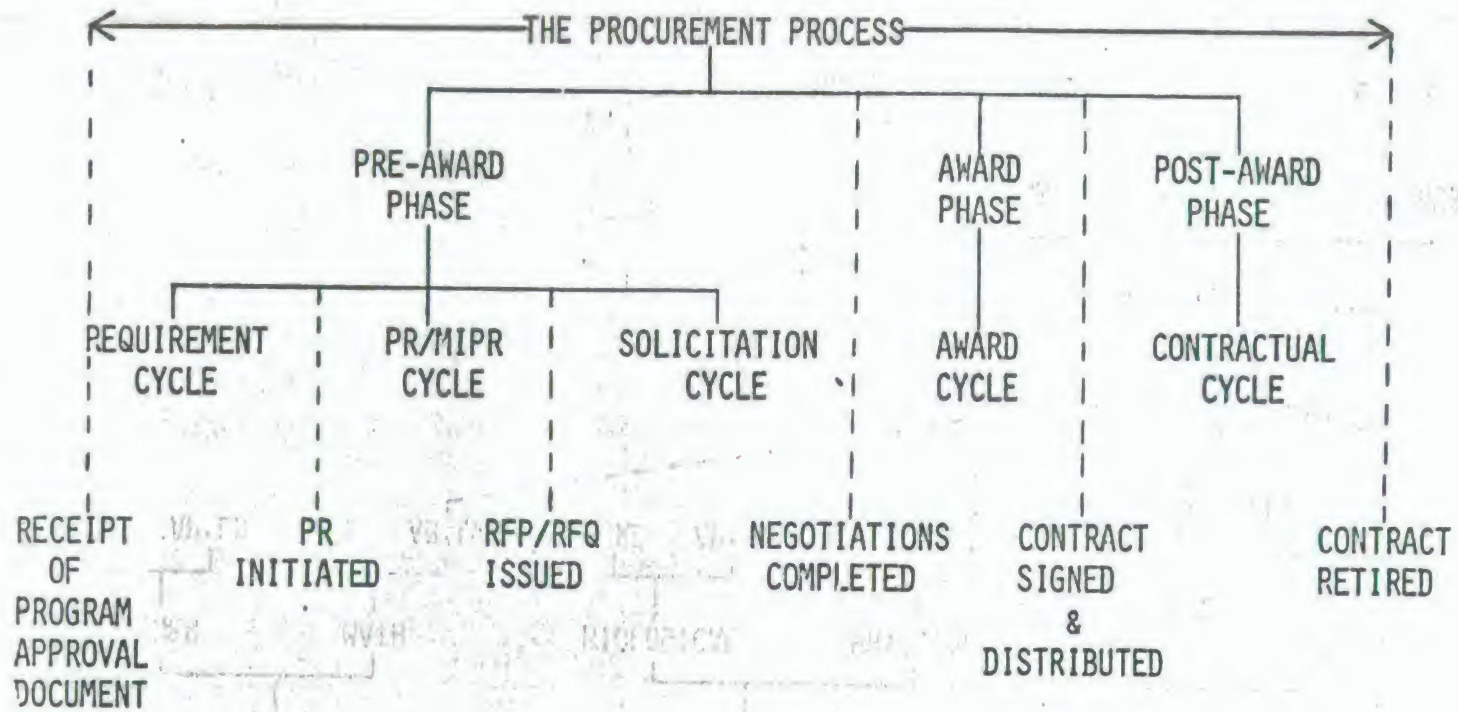
INPUTS
INPUTS
ACQUISITION PROCESS
SYSTEMS
LOGISTICS
OTHERS
MAINT
PROCUREMENT
SUPPLY
OTHERS
PROCUREMENT PROCESS



THE PROCUREMENT PROCESS
PRE-AWARD PHASE
AWARD PHASE
POST-AWARD PHASE
REQUIREMENT CYCLE
PR/MIPR CYCLE
SOLICITATION CYCLE
AWARD CYCLE
CONTRACTUAL CYCLE
RECEIPT OF PROGRAM APPROVAL DOCUMENT
PR INITIATED
RFP/RFQ ISSUED
NEGOTIATIONS COMPLETED
CONTRACT SIGNED & DISTRIBUTED
CONTRACT RETIRED

* THE PROCUREMENT PROCESS

PRE-AWARD PHASE

INPUTS → NEED GENERATION → REQUIREMENT CYCLE

RECEIPT OF PROGRAM APPROVAL →

REQUIREMENT DETERMINATION	REQUIREMENT PACKAGE	PR ISSUED

REQUIREMENT DETERMINATION:

- REQUIREMENTS
- RISK ANALYSIS
- DETERMINATIONS & FINDINGS
- APPROPRIATIONS
- BUDGET AUTHORIZATION

REQUIREMENT PACKAGE:

- PERFORMANCE SPECS
- DRAWINGS
- FEDERAL SPECS
- MIL STANDARDS
- MIL SPECS
- QUALIFIED PRODUCTS LIST
- CONTRACT REQUIREMENT LIST
- MAINTAINABILITY
- RELIABILITY
- COMMERCIAL ITEMS
- GOVERNMENT PROPERTY

*PERVASIVE THROUGHOUT THE PROCUREMENT PROCESS:

- PROCUREMENT ETHICS
- CONTRACT MANAGEMENT

THE PROCUREMENT PROCESS

PRE-AWARD PHASE

PR/MIPR CYCLE

- PR RECEIVED
- PROCUREMENT PLANNING
  - TYPE OF ACQUISITION
  - RESOURCES
  - LEGAL
  - CLAUSES
  - TYPE OF CONTRACT
  - KIND OF CONTRACT
  - BIDDER'S LIST
  - TYPE OF PROPOSAL
  - ADMINISTRATION
  - ADVANCED PROC. PLAN
- SOW
  - PERFORMANCE SPECS
  - DRAWINGS
  - FEDERAL SPECS
  - MIL STANDARDS
  - MIL SPECS
  - QUALIFIED PRODUCTS LIST
  - CONTRACT DATA REQUIREMENT LIST
  - MAINTAINABILITY
  - RELIABILITY
  - COMMERCIAL ITEMS
  - GOVERNMENT PROPERTY
  - OTHER ADDITIONS
- SOLICITATION ISSUED/ RELEASED
  - ADVERTISED
  - SOLE SOURCE
  - MULTI SOURCE

THE PROCUREMENT PROCESS

PRE-AWARD PHASE

SOLICITATION/EVALUATION CYCLE

- RESPONSE TYPES
  - SOLICITED
  - UNSOLICITED
- TECHNICAL EVALUATION
  - LABORATORY
  - ENGINEERING
  - MATERIALS
- DECISION
  - YES - CONTINUE
  - NO - RETURN TO REQUIREMENTS PACKAGE FOR RE-EVALUATION

THE PROCUREMENT PROCESS

PRE-AWARD PHASE

SOLICITATION/EVALUATION CYCLE

- PROPOSAL AUDIT
  - DEFENSE CONTRACT AUDIT AGENCY
- CONTRACTOR CAPABILITY REVIEW
  - SHOULD COST
  - PRODUCTION READINESS REVIEW
  - PRE-AWARD SURVEY
- COST ANALYSIS/ PRICE ANALYSIS
  - ACCOUNTING
  - TYPES OF COST
  - TECHNIQUES (COST ESTIMATIING RELATIONSHIPS)
  - COST DESIGN
  - PROFITS
  - PRICE COMPETITION
  - DIFFERENTIATION
  - WEIGHTED GUIDELINES

THE PROCUREMENT PROCESS

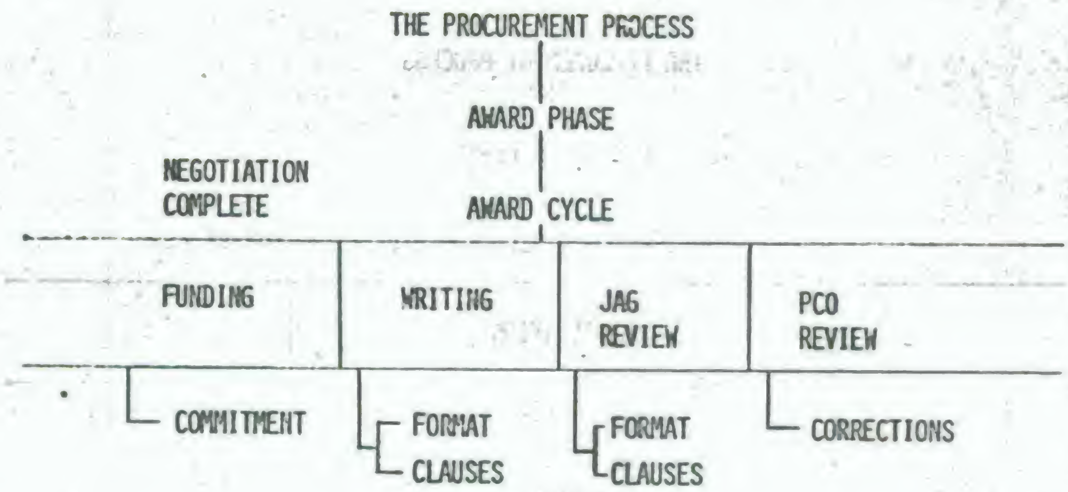
PRE-AWARD PHASE

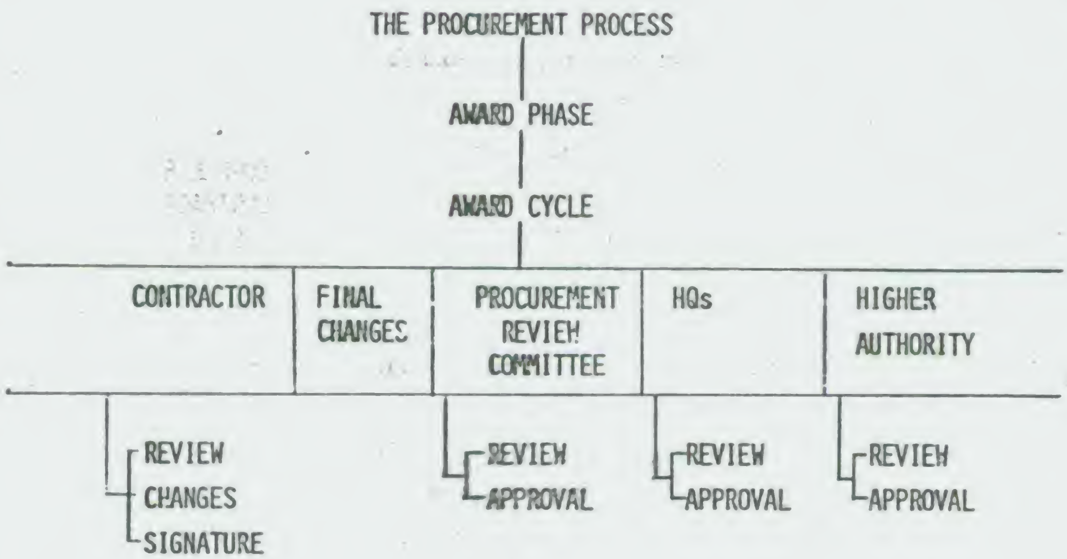
SOLICITATION/EVALUATION CYCLE

SOURCE SELECTION

NEGOTIATION

- OBJECTIVES
- STRATEGY
- TACTICS
- THEORIES
- EXPLORATORY
- MULTI AWARDS
- PRICING NEGOTIATION MEMORANDUM
- DECISION MODELS


THE PROCUREMENT PROCESS
AWARD PHASE
NEGOTIATION COMPLETE
AWARD CYCLE
FUNDING
WRITING
JAG REVIEW
PCO REVIEW
COMMITMENT
FORMAT
CLAUSES
FORMAT
CLAUSES
CORRECTIONS


THE PROCUREMENT PROCESS
AWARD PHASE
AWARD CYCLE
CONTRACTOR
FINAL CHANGES
PROCUREMENT REVIEW COMMITTEE
HQs
HIGHER AUTHORITY
REVIEW
CHANGES
SIGNATURE
REVIEW
APPROVAL
REVIEW
APPROVAL
REVIEW
APPROVAL

THE PROCUREMENT PROCESS

AWARD PHASE

AWARD CYCLE

COMPLETE
CONTRACT
ISSUED

ANNOUNCEMENT OF AWARD	CONTRACT DISTRIBUTION

- ANNOUNCEMENT OF AWARD
  - CONGRESSIONAL
- CONTRACT DISTRIBUTION
  - CONTRACTOR
  - PRIME CONTRACTING OFFICER
  - GENERAL ACCOUNTING OFFICE
  - OTHERS
  - OBLIGATION

THE PROCUREMENT PROCESS

POST-AWARD PHASE

PRODUCTION BEGINS

CONTRACT ADMINISTRATION CYCLE

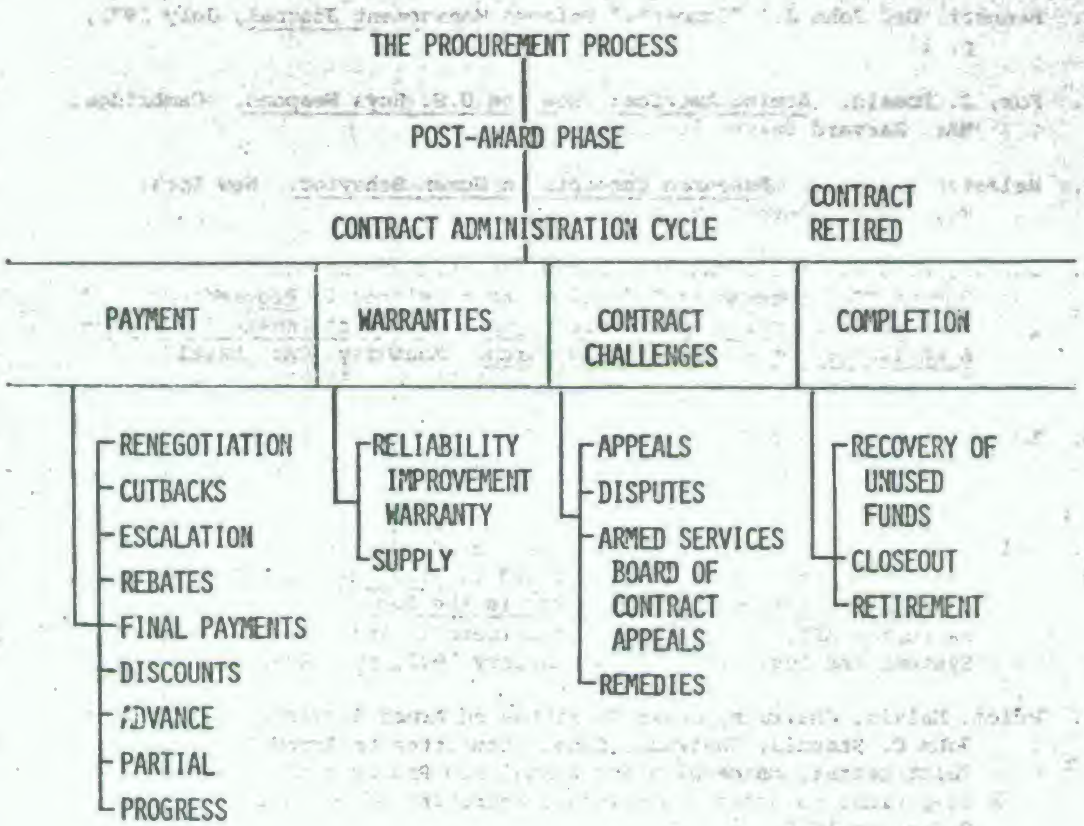
- ASSIGNMENT
  - AGENCY
  - CONTRACTING AUTHORITY DELEGATIONS
  - SECONDARY DELEGATION
- SYSTEM COMPLIANCE
  - QUALITY ASSURANCE
  - DESIGN ENGINEERING INSPECTION
  - FIRST ARTICLE CONFIGURATION INSPECTION
- PERFORMANCE MEASUREMENT
  - AIMS
  - C/SCSC
  - PROGRESS PAYMENTS
  - MILSCAP
  - AMIS

THE PROCUREMENT PROCESS

POST-AWARD PHASE

CONTRACT ADMINISTRATION CYCLE

PRODUCT/SYSTEM ACCEPTANCE	TERMINATION	DELIVERY
QUALITY CONTROL	NO - CONTINUE	SCHEDULE
CHANGES	YES - TERMINATE	REQUIRED DELIVERY DATE


THE PROCUREMENT PROCESS
POST-AWARD PHASE
CONTRACT ADMINISTRATION CYCLE
CONTRACT RETIRED
PAYMENT
WARRANTIES
CONTRACT CHALLENGES
COMPLETION
RENEGOTIATION
CUTBACKS
ESCALATION
REBATES
FINAL PAYMENTS
DISCOUNTS
ADVANCE
PARTIAL
PROGRESS
RELIABILITY IMPROVEMENT WARRANTY
SUPPLY
APPEALS
DISPUTES
ARMED SERVICES BOARD OF CONTRACT APPEALS
REMEDIES
RECOVERY OF UNUSED FUNDS
CLOSEOUT
RETIREMENT

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STANDARDS FOR THE CONDUCT OF ACQUISITION RESEARCH

Robert Judson
Executive Director
Navy Center for Acquisition Research
Naval Postgraduate School

Standards are emerging both from within agencies conducting research and from legislative branch reviews of agencies activities.

What has led the legislative branch to review these research activities? Generally, it has been concluded that reliance on functional policy specialists, ad hoc management fixes and regulatory mechanisms to identify and solve chronic problems and make substantive improvements in the procurement area has not worked. It was concluded that a leading candidate as an alternative to these previous efforts is an organized approach to procurement research.

Again, why should the legislative branch be concerned with the details of procurement research programs? It was concluded that necessary policy redirections require a series of operational changes in agency procurement and acquisition practices which touch both legislative and executive branch responsibilities.

Considerations regarding standards for the conduct of research: Basic definitions

Research critical investigation into an agency's procurement and acquisition processes with the objective of improving their effectiveness; includes development of new procedures, techniques and approaches, as well as experimentation aimed at gaining new insights or making new discoveries about these processes.

Acquisition usually used in connection with major systems and includes the entire spectrum of activities starting with an agency's determination that it needs a new or improved capability for an assigned mission through to operational use. (This definition is consistent with new standards and areas for the conduct of research suggested by OMB Circular A-109 and revised DOD Directives 5000.1 and .2. The new milestone 0 to 1 sequence involves "managing the determination of what we need." The integrity of pursuing this decision making process should be guided in part by the business management judgments from the "procurement community." This is a role from which the procurement community has traditionally excluded itself.)

Procurement is either "independent" or an important subset of the acquisition process. As an independent process, it starts when a procurement request is received in a purchasing office and continues through award and administration.

The distinction between acquisition and procurement does not degrade the importance of one or the other, but it is a useful distinction when examining whether we are conducting relevant research in both areas.

Standards for expectations of what research ought to provide.

1. basis for problem identification and problem solving; these should be the underlying, root cause problems and research should distinguish cause and effect relationships in problem identification.

2. basis for a corporate memory; a "lessons-learned" clearing-house is required as part of the data base for the conduct of research.

3. basis for developing procedures for new policies; before the issuance of new policies, alternative approaches should be identified, explored and tested.

4. independent research, looking to long-range, innovative improvements, not constrained by immediate problem solving.

5. support for the development of education and training programs; what organizations are concerned, or should be, with standards for the conduct of research.

Office of Federal Procurement Policy

Role: Government-wide research leadership and coordination

As required by P.L. 93-400, OFPP has a responsibility for "promoting and conducting research in procurement policies." It will be acting in concert with the Federal Procurement Institute and has already initiated some major systems research activities.

Federal Procurement Institute

Role: "Promote, monitor and conduct research to develop business methods and management techniques that will advance the state of the art in procurement."

The principal objective should be to encourage and support existing programs but FPI take research initiatives where gaps or omissions are determined to exist in existing research coverage.

Acquisition Executives

Role: Should have overall research responsibjlity and guidance within an individual service (agency).

The acquisition executive, required to be designated under OMB Circular A-109, would be a logical focal point for agency research responsibilities and guidance.

Agency Operating Elements

Agency Research Activities

The traditional relationship of sponsor and performance would continue.

Standards for basic research capabilities

1. Establishment of a clearing-house for the identification and sharing of research data. This could be covered by the FPI and OFPP.

2. Establishment of an information data base, including: bibliographies, abstracts, studies and reports together with directories of individuals, associations, professional societies and their journals, completed research of both the public and private sectors.

3. Establishment of a professional research cadre with a mix of professional backgrounds and experience.

4. Effective access to research users and procurement practitioners.

5. Establishment of a system for developing and refining long range research areas of concern, and allocating resources to these areas.

6. Establish sustained support and sponsorship from top management and middle level operating elements for a program of procurement research.

WHAT ARE WE BUYING HERE?

Daniel E. Strayer, Lt Col, USAF, Ph.D.
Lyle W. Lockwood, Maj, USAF
Air Force Business Research Management Center

"The time has come," the Walrus said,
"To talk of many things:
Of shoes—and ships—and sealing wax—
Of cabbages—and kings—

Lewis Carroll

PART I - INTRODUCTION

Acquiring complex systems involves the need to speak of many of the items referred to in Lewis Carroll's famous quotation. Similar techniques and approaches are employed to buy a vast range of products. Indeed, it is precisely this variety of acquisition concerns which has caused us the gravest difficulties in the past, and continues to plague and thwart us. Although the system acquisition process has long been the topic of high level study, we do not yet have anything approaching a consensus as to what ought to be done. In fact when the range of concerns is boiled down to the essentials, it is no exaggeration to observe that requirements management is one of the most difficult problems facing today's acquisition managers.

For most complex items we do not presently enjoy a clear and generally agreed on definition of requirements. This paper is dedicated to the proposition that the next substantial improvement in the management of weapon acquisition process must come from improved understanding, and ultimately rigorous management of requirements themselves. We can no longer rely on gross control of the total flow going through the system. To be effective, we must manage the contents of our requirements pipeline!

PART II - THE REQUIREMENTS ESTABLISHMENT PROCESS

Consider the graphical representation of the USAF requirements process set forth in Figure 1. (While the USAF process is used as an example here, it is considered representative of the entire DOD acquisition requirements generation process.)

Figure 1

USAF Requirements Process

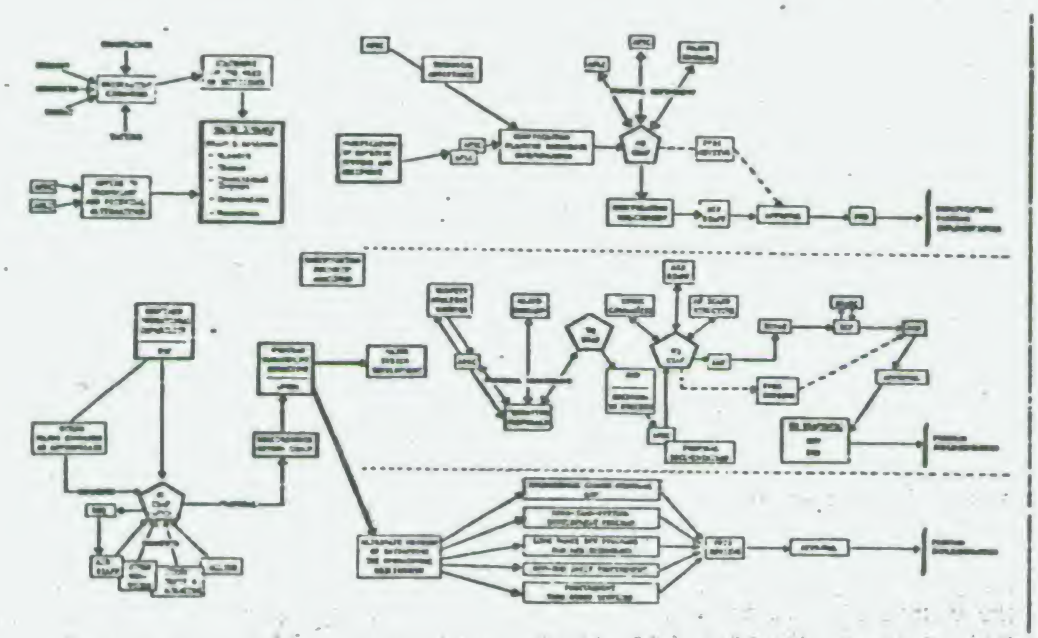


Figure 1 illustrates the management system that emphasizes primarily one portion of the requirement--the operational need for the acquisition. The elaborate system of checks, balances, and consultation exists to satisfy that need. All of the steps in the process lead to a common end--establishment of a program to satisfy the operational need.

There is no argument with the essentiality of this type of review system. However, it is now time to address other components of the problem. The existing process turns on the main valve (the requirement itself) but it does not yet address, in sufficient detail, what shall be included in the content pipeline. A clearer understanding of what is included in requirements must be established if life cycle cost, design-to-cost, and other objectives are to be met. Only then can we clearly understand exactly what we are buying. And when we do that, we will be in a position to manage the introduction of requirements

into the contract and thus to greatly improve overall performance. Let us consider how requirements might be more precisely categorized so as to permit a more refined managerial approach.

PART III - A NEW REQUIREMENTS CATEGORIZATION

The total system requirements flowing through the process pipeline can be divided into six distinct categories. These categories are:

a. Mission requirements.

b. Operating characteristics.

c. Design standards and specifications.

d. Management systems standards and specifications.

e. Legal obligations.

f. Programming requirements.

All of these are communicated to industry by the procurement and program management process and create both the administrative and the technical environment in which the government's need, i.e., requirements, will be fulfilled by the contractor. Although they are considered contractually equal, they are in fact quite different.

Mission requirements ultimately quantify the need for acquisition. Included in this category are functional definitions, e.g., transportation of troops, cargo; destruction of targets; transmission of messages; etc. Also included in this category are surrogates for functions commonly called performance parameters. Examples of these are: speed, range, altitude, capacity, effectiveness, accuracy, etc. In total, the mission requirements define the purpose of the system. They spell out what the system is expected to accomplish. They deal with accomplishment in the mission performance mode, that is, in a brief, usually mission-defined, time span. Thus they are almost always measured instantaneously during the test and operating modes. Measurement, and therefore evaluation, can be both rapid and reasonably accurate.

Operating characteristic requirements quantify many of the efficiency indicators of the system. They include much longer time consideration because they combine the functional components of life cycle cost--reliability, maintainability, quantity and quality of operators, expected useful life, logistics support, and component interchangeability standards. These requirements impact on the system's design. However,

they are not usually measurable at the same time that mission requirements are measured. The success of satisfying such life cycle considerations is measurable only over time, frequently a rather long time continuum.

Design standards and specifications deal with the transformation of mission requirements and operating characteristics into hardware. They describe specific knowledge of measurement inputs into the design process. Included in this category is the stated order of preference for specifications and standards--components, material, and processes. The order of preference results from the belief that specifications and standards are the technical corporate body of knowledge. They are codified lessons learned. As such, they can become inflexible guidelines or directives to the contractor. We impose them as design constraints in order to avoid new development costs, assure standardization, strive for competitive procurement of homogeneous products, and avoid costs of nonstandard components. All of these are worthy and desirable goals.

Management systems specifications and standards either specify the nature of an organizational behavior pattern or require the disclosure of specific managerial information. This category is exemplified by such things as program management requirements, system engineering management plans, reliability program plans, configuration management plans, cost schedule control systems, and the like. The purpose of each category in this requirement is common: to elicit a desired level of contractor behavioral or managerial response.

Legal obligations include both mandatory and bilateral requirements that are placed on the contractor and the government program office by basic contract law, federal law, or agency regulations. Legal requirements are designed to accomplish various national and program management objectives. These have various political, economic, technical, or social dimensions. Examples are many and include the Walsh-Healey Act, OSHA, environmental protection regulations, equal employment opportunity regulations, the cost accounting standards, and many more. In addition to the legal obligations mandated by law, bilateral requirements are frequently agreed on by the contracting parties and include type of contract, method of payment, restitution, warranties, corrections of deficiencies, government-furnished property or services, forward pricing agreements, adjustments for abnormal price escalation, and the like.

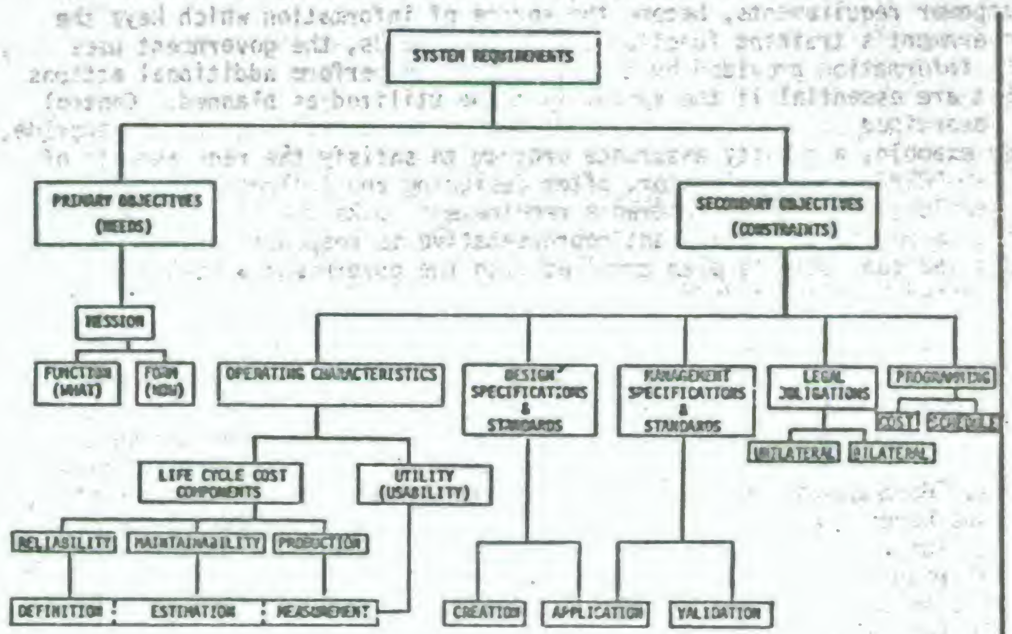
Programming requirements are allocations of total program costs and quantities into annual or other periodic partitions. These are usually described in terms of funding ceilings, time-phased budgets, and delivery schedules. In an unconstrained mode, these requirements are a statement of when the mission need must be satisfied. These requirements are initially defined by the using command and modified by planning staffs and development agencies. Further modification or adjustment of programming requirements are made throughout the federal budgetary process. The resolution of programming requirements and mission requirements has been the focus of annual debate at the national level. Most of this

audience is well aware of the attention given to these requirements by the full complement of acquisition managers and staffs.

Figure 2 breaks down the systems requirements into the six categories just described. Note that these are both primary objectives and secondary objectives and can thus be referred to as needs on the one hand and constraints on the other. By adopting the needs and constraints viewpoint, we can better understand how the conflicts so frequently observed are generated and sustained.

Figure 2

Systems Requirements Categories



PART IV - WHAT REQUIREMENTS BUY

If requirements did nothing more than sit in the contract, it might not be too bad. However, each category of requirements generates actions

on the part of the contractor, reactions on the part of the government, and costs for both. Each requirement in each category causes a flow between the government and the contractor. A requirement is communicated to the contractor. He transforms the requirement into hardware or information and returns that to the government. The government then returns either money or information to the contractor, and so the process goes. The government performs then two primary functions with the information it has received: it employs it as an input to operations or uses the information to measure and control ongoing operations. Requirements generate actions, and actions cost money.

Examples of each category of utilization abound. A use function is accomplished when the Air Training Command initiates a training program to provide the quantity and quality of operators that the contractor's information says will be needed to operate the system at the level required. Here the systems operating characteristics, translated into manpower requirements, become the source of information which keys the government's training functions. In other words, the government uses the information provided by the contractor to perform additional actions that are essential if the system is to be utilized as planned. Control is exercised somewhat differently. The contractor is required to provide, for example, a quality assurance program to satisfy the requirements of MIL-Q-9858A. The contractor, after designing and implementing a program to satisfy the quality assurance requirement, asks the plant representative to review it. The plant representative is responsible for assuring that the contractor's plan compiles with the government's need as expressed by the standard.

In both circumstances, cost and schedule impacts are associated. Indeed, it can be argued that cost and schedule can operate as an objective, i.e., a requirement, or as a constraint depending upon the situation. However, each requirement category clearly consumes both resources and time from both the contractor and ultimately the government. Good management, therefore, should establish the relative cost versus benefit of each requirement in order to evaluate its net contribution. Yet, as presently organized, management cannot review the total requirements and assess their costs and benefits before they are placed on the contractor. In fact, there is no entity which is responsible for doing so!

PART V - HOW TO BUY REQUIREMENTS

If this description of requirements categories is true, and all requirements can be satisfactorily categorized accordingly (and several practitioners have assured us that that is the case), the next question to be addressed is that of usage. How should we buy requirements?

Clearly this is a time sensitive process. Various requirements have their primary roles at different times in the development process. Mission and performance requirements concentrate heavily on the front-end, prior to DSARC I, DSARC 0. Operating characteristics tend to be more heavily represented in the operation and support phase of the weapon system's existence. The contractual terms and conditions exist throughout the contractual relationship while the management systems specifications and standards tend to be more important during the full-scale development and production phases.

By employing the requirement categories to provide a framework management can:

a. Identify the total set of requirements that will be applicable to an acquisition program--and more importantly determine which will not be used,

b. Determine the appropriate program phase for introducing combinations of requirements that will be applicable,

c. Assign responsibility to the appropriate organizational elements for evaluating the requirements under their control,

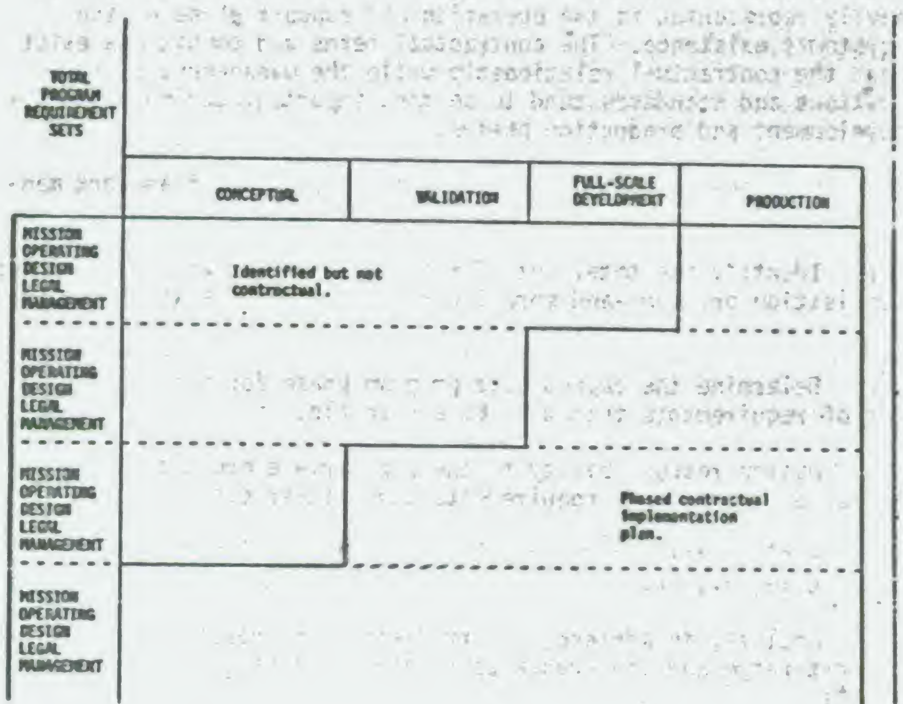
d. Assign cost and worth values to each requirement, and/or requirement category, and

e. Analyze, in advance, the trade-offs and resolve the conflicts between short-range and long-range costs and benefits associated with requirements.

In principle, it may be possible to so categorize requirements as to require much less during the conceptual phase building gradually towards full imposition of the applicable requirements when the system enters production. Such phase requirement management could stimulate innovation, in both technical and management aspects of systems acquisition, as well as improving resource utilization. Figure 3 illustrates how this might be conceived.

Figure 3

Phased Requirement Introduction



PART VI - OPPORTUNITIES AND CHALLENGES

Although top management has placed increasing emphasis on various requirements aspects over recent years, much remains to be done. Specification tailoring, use of commercial equivalents, and other approaches have yet to be fully developed. In short, there are many opportunities for management in the requirements dilemma. A first, and necessary step is a validation of the scheme just outlined. Management can take the initiative in arranging for a meaningful test. Assuming that that is successful, and we believe it would be, management can then properly assess the institutional approaches to its proper utilization. Researchers can, of course, assist at each step of the way.

From a research viewpoint, the requirements process is largely unexplored. Our review of the published literature, and our discussions with knowledgeable managers, revealed less than ten studies which deal

directly with the requirements measurement issue. None of these are substantiated by either carefully conducted case studies or quantitative research. Thus, while the process of generating the requirement, expressed in terms of need, in the management review of acquisition performance has been studied, it is a fact that the substance of requirements--their form, costs, and benefits, etc.--have yet to be subjected to serious inquiry.

Serious inquiry and ultimately rigorous management of system requirements can help us insure that we get what we need--and no more. And that would help us avoid figurative experience with the remainder of Lewis Carroll's quotation which began this paper:

"And why the sea is boiling hot--
And whether pigs have wings."

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SOURCE SELECTION

THE USE OF FUNCTIONAL PURCHASE DESCRIPTIONS FOR ADVERTISED PROCUREMENTS

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ABSTRACT

Important realities often overtake the otherwise desirable objectives to be obtained by the use of formal government specifications in advertised procurements.

The most critical reality is that users of materials procured under advertised procedures don't always get equipment that satisfies their actual needs.

Another reality has been that initial bid price can be a misleading indicator of ultimate cost to the government. While existing procedures routinely anticipate awards based on considerations other than bid price alone, the preponderance of advertised awards are made on the basis of low bid.

Proposals have been made to utilize functional purchase descriptions as an alternative to costly and restrictive formal government specifications.[1] Such proposals carry the potential benefit of meeting user needs at a least ultimate cost. These same proposals also raise difficult award determination considerations.

Research suggests that:

1. Guidelines exist for establishing valid functional purchase descriptions.

2. Functional purchase descriptions can be reconciled with equitable award determination procedures based on a "least cost" standard which can include both bid and user costs.

3. Functional purchase descriptions have the potential to lower user costs for particular kinds of equipment purchases, as well as lower or eliminate the costs associated with writing and administering formal government specifications.

4. Competition can be increased and made a more useful device by using functional purchase descriptions to elicit total product competition rather than the narrow initial price competition associated with the use of formal government specifications.

SOME PROBLEMS

User Needs and Costs

Procurement systems which impose mandatory sources of supply, formal government specifications, directed procurement methods and other restrictive procedures may make it difficult for a user to satisfy actual needs.

However, even under todays procedures, where extensive documentation is required for all exceptions to formal advertising, a user often can obtain just what is needed if there is enough time and persistence to prevail in the face of procurement complexities.

For advertised procurements, it is well established that Federal agencies can:

- determine their needs

- use "restrictive" specifications

- consider factors other than price in determining award[2]

The precedence of GAO decisions granting this latitude suggests a flexability in decision making which is not characteristic of actual practice. The hassle of reviews, documentation, time delays, and limited numbers of procurement personnel do not make actual need concerns a readily acceptable decision standard for the average procurement situation.

In evaluating the present procurement system, the cost and complexity of communicating needs must be considered. A significant part of this cost typically resides in the development of formal government specifications, which almost always trail the development of commercial product counterparts.[3]

Often, "improvements or simplications" added to user requests by review authorities result in products which will not meet actual user needs. Formal specifications and formal statements of requirements tend to become cluttered with clauses that often do not even provide an adequate basis for bidding.[4]

Another important aspect of evaluating our present procurement system is to note that the total cost of satisfying user requirements is directly affected by the timeliness of delivery and quality of product. Our economy, which now places a premium on labor, means that logistics concerns must consider the cost of idle personnel and equipment caused by late delivery. It also means that life cycle costs involved with maintenance, service, downtime, and repair account for the majority of all costs associated with procurements.

In the face of these cost realities, limiting buyer choice to initial bid prices is naive and unnecessary. The management of sealed bid procurements must mature to consider the cost realities overtaking advertised procurements.

Specifications[5]

There are approximately 40,000 federal specifications and industry standards used for federal procurements.[6] Many of these specifications are obsolete.

Virtually all specifications cite other specifications and publications and incorporate them by reference. For example, the Commission on Government Procurement identified 313 specifications for the procurement of an ordinary light bulb.[7]

Other specification-related problems cited by the COGP included:

- Purchase under a formal specification where commercial products are available usually results in greater cost to the government.

- Use of formal specifications may deny the government current technology.

- Strict administration of specifications for commercial products discourages potential suppliers, thus restricting competition.

- Specifications establish minimal quality levels and there is no regular procedural device for encouraging superior quality.

Federal specifications may have positive qualities such as:

- providing a basis for standardization

- establishing minimum quality levels

- supporting apparent competitive procurements

However, the CGOP noted that:

> "If specifications are obsolete, many commercial products do not meet their requirements. This in effect limits competition, defeats the intent of the government, and deprives it of the advantage of the technologically dynamic open market."[8]

VALID PURCHASE DESCRIPTIONS

A prerequisite for the use of advertised procurement is the establishment of a basis for full and fair competitive bidding to a common standard. Procedures surrounding the use of advertised procurement are designed to preclude favoritism, collusion or fraud.

The principal device to establish a common standard has been the use of formal government specifications.

Thus, any effort to reform current advertising procedures must consider what constitutes an acceptable bid purchase description in lieu of a formal specification.

In order to be valid, purchase descriptions must:

- accurately reflect the needs of the government

- avoid unduly restrictive requirements which tend to limit competition without satisfying a real need[9]

Current ASPR standards derive from a long history of GAO decisions relating to "brand-name-or-equal" procurements, involving the use of a particular type of purchase description. This history, together, with related GAO decisions and the regulatory responses which followed these decisions, are the precedents relied on to evaluate what constitutes a valid use of functional purchase descriptions.

It is relevant to note that functional, or "performance oriented specifications" have been cited by GAO as best protecting the government's interest in obtaining minimum needs at "favorable prices" while insuring that all manufacturers have "an opportunity to compete for government purchases."[10]

Responsibility for Establishing Functional Purchase Descriptions

Ultimately, the government must perceive and determine its needs, especially considering the "second guessing" that could attend the use of a functional purchase description approach to procurement.

> "In the orderly conduct of its business, the government as a buyer may not be placed in the position of having to share such discretionary authority to prescribe its needs with one of its potential suppliers who is unable to adapt its product to the needs of the government."[11]

While the government must ultimately retain control over the determination of its needs, the use of functional purchase descriptions may invite a preliminary round of "competition" for ideas as to what the government ought to specify as mandatory or desirable functions to be obtained. In commercial areas of rapid technology change, such as automatic data processing functions, there is a distinct advantage to a user to search, in various ways, to become aware of what functional needs can be met by the commercial market-place

Here, the user is relying on the capabilities of existing commercial equipment to set functional requirements. The government's "specification workload" has been assumed by the normal activities of the private sector. Potential suppliers response to, or anticipation of, needs make the user aware of what is possible. This is the essence of reliance on the private sector.[12] Moreover, government needs could be discussed in pre-solicitation conferences, open to advocacy and challenge by potential bidders. Some form of a mandatory pre-bid conference, or its equivalent, probably should be used to assure a comprehensive consideration of existing technology.

Source Limitation Situations

Having been made aware of private sector functional capabilities in evolving agency needs, the government may face certain source limitation realities in meeting government needs with existing private sector equipment.

The basis for resolving issues surrounding source limitation concerns has been an "actual needs" standard. For example, sole-source awards are acceptable if necessary to meet "actual needs."

Since establishment of specifications reflecting actual needs is the responsibility of the procuring agency, the government has not violated either the letter or spirit of formal advertising statute in the past because only one bidder could supply its needs, provided the specifications were reasonable and necessary for the purpose intended.[13] This same standard should be available for functional purchase descriptions.

Patents, as another example, may be involved in equipment necessary to satisfy a functional need. GAO decisions consistently have held that it is permissible to specify a patented device ". . .so long as that patented device is, in fact, representative of the actual needs of the purchasing agency."[14] Thus, a given functional purchase description might involve a need met only by a patented item.

Stipulations regarding the independent testing of equipment have also been permissible. There was concern over a Comptroller General decision which held that a requirement that articles supplied to the government bear the Underwriters' Laboratories label, or any similar emblem of a private organization, "is not generally justified."[15]

Subsequently, it was argued that agencies of the federal government should be permitted to utilize the recognized good management procedure adopted and followed by private industry. Finally, GAO backed off, "we will interpose no objection. . .if it be determined administratively in each case that such a provision is in the interest of the United States".[16] GAO felt that "in certain cases it might be proper to include. . . a requirement that such articles shall conform to standards adopted by recognized private testing organizations where such standards are generally recognized and accepted in the industries involved and pertinent to the government's needs."[17]

From the precedent of latitude to state actual needs with restrictive conditions in formal specifications, so functional purchase descriptions should reflect the same degree of reality in meeting actual needs.

"Salient Features" of Functional Purchase Descriptions

A paramount consideration in the use of functional purchase descriptions is to establish salient functional characteristics for equipments. This must be done with considerable forethought and restraint.

A regulatory "test" has evolved for salient characteristics in general, in response to GAO decision:

"purchase descriptions should set forth those salient physical, functional, or other characteristics of the referenced product which are essential to the needs of the government."[18]

Again, the use of functional purchase descriptions should be guided by GAO's rule in "brand-name-or-equal" decisions that:

"A bidder offering. . .products should not have to guess as the essential qualities of the. . .item. . .they are entitled to be advised in the invitation of the particular features or (functional) characteristics of the. . .item which they are required to meet. An invitation which fails to list all the characteristics deemed essential or lists characteristics which are not essential, is defective."[19]

Thus, functional purchase descriptions should reflect essential functional characteristics or user cost considerations.[20]

While pre-solicitation conferences or other techniques may be utilized in part to determine needs, the needs must be settled in advance of the issuance of the invitation for bids and such actual needs should be set forth in the bid as salient characteristics, (functional requirements),[21] together with essential considerations relating to user costs.

Response to Purchase Description

How a bidder responds to a functional purchase description will determine whether the bid is even considered.

The descriptive literature clause in Federal Procurement Regulations (FPR) and Armed Forces Procurement Regulations (ASPR) provide that the "Contracting Officer shall insert. . . details with respect to significant elements such as. . .performance characteristics. . .or operation, as appropriate."[22]

In responding to an invitation employing a. . .purchase description, the responsiveness of a bid should depend not on whether the bidder believes or even knows, that his product meets the purchase description, but whether the procuring activity can so determine from the information submitted with the bid.[23] ". . .descriptive data requirement. . .is a material requirement which cannot be waived. Merely quoting back the description in the specifications (functional purchase description) without exception would not in itself fulfill the descriptive data requirement. . . "[24]

It should be noted that the fact that a particular firm may be unable or unwilling to meet the requirements of a solicitation is not sufficient to warrant a conclusion that the specification (purchase description) is unduly restrictive.[25]

A blanket statement by a bidder offering to meet all requirements (purchase description) does not substitute or compensate for inadequate descriptive data, and rejection of (such a) bid as nonresponsive is therefore required.[26]

A bidder is free to offer a product with features in excess of those deemed salient, and the government's acceptance of such a bid does not thereby retroactively alter the list of

salient features.[27] Such features might affect user cost determination in establishing "least cost" to the government among the bids received.[28]

AWARD DETERMINATION ALTERNATIVES

In considering responsiveness and costs, sealed bid awards could be based on one of the following:

1. Award self contained, that is, initial bid price is the sole standard for determining award, the traditional advertised procedure.

2. IFB sets forth mandatory functions and desirable functions or characteristics. A matrix of dollar values assigned to desirable functions is stated in the IFB guide to all bidders. The net cost impact of desirable features offered or not offered as a part of bid response are considered in the determination of an award.

3. IFB sets forth mandatory and desirable functional features and in addition, provides for user cost calculations in order to determine "lease cost" to the buyer for bids received. Award is determined from netting three figures: bid prices for mandatory features; net cost impact of desirable features offered or not offered; user costs for each bid, based on use cost considerations set forth in the IFB.

Because functional purchase descriptions should invite a range of approaches, award determination techniques must link dissimilar responses.

The most complex form of award determination is one that calculates "lease cost" for the government. Least-cost is also the most realistic approach for award determination where user costs can be identified and attributed to equipment characteristics.

Examples

Following are examples suggesting the use of functional purchase descriptions in IFBs.

These examples are based on automatic data processing equipment purchases. The reasons for selecting this type of product for illustration are the following:

- The government is the largest buyer of ADPE equipment and services.

- There are no standard Government procurement specifications for ADPE equipment.[29]

- The computer market is highly competitive.[30]

- Computer technology is highly dynamic.

- ADPE purchases represent some of the most time consuming and complex purchases under existing procurement procedures.

- ADPE procurement continues to attract innovative procedural treatment at both state and local government levels as well as the federal government level.[31]

- If the precedents and tests for adopting functional purchase descriptions can be made for ADPE equipment, simple analogies to more routine equipment purchases should make them candidates for a functional purchase description approach.

Example I:

Least Cost Source Selection Technique [32]

IFB Includes:	Bidder Response:	Award Determination Considers:
Mandatory: Hardware, software, services, described as functional requirements necessary to meet actual needs. Functional statements encourage innovation and maximum competition in meeting needs.	Must agree to meet mandatory functional requirements or bid is eliminated from further consideration.	Bid costs on a full system life costing analysis basis (e.g. 5 years, 7 years, or whatever time period is specified.)
Desirable: System characteristics to enhance or fulfill some aspect of actual need. Dollar values assigned to desired functional characterisitcs based on calculated worth to agency, i.e. cost avoidance of additional outside purchase, in-house performance costs or sacrificing some aspect of functional capacity.	May or may not respond to any or all of desired system charactersitics; may or may not charge for any response(s).	Evaluation of response to each desired characteristic: (1 Offered at no charge, or offered at charge below predetermined value, subtract either assigned dollar value or difference, from bid price. (2 Not offered or offered at charge exceeding predetermined value, no deduction from bid price.
User Cost Considerations: System life considerations which can be readily isolated and calculated for various bidder responses (e.g. requirements for: power, space, supplies, air-conditioning staff)	Notice given in IFB as to these user cost factors and bidder response must enable buyer to calculate system life cost implications.	Net of system life cost dollar impacts in bidder approach.

The least total cost evaluation technique nets three calculations to determine an award:

1. bid prices for "mandatory requirements"
2. cost avoidance value of "desired items, features or additional system requirements" offered (user pre-determined values for additional functions)
3. user costs (user determined operational cost considerations expressed in IFB and calculated for each bidders response)

Source selection is based on the proposed system having the "least cost", i.e. combination of bid costs for hardware, software & services; net of values for desirable items offered or not offered; related user costs.

With a least total cost evaluation technique, the functions of bid items listed as mandatory are not "evaluated". A bidders' ability to satisfy mandatory functions is determined, utilizing pre-award survey or other techniques if necessary. If a bidder fails to satisfy "mandatory requirements", that bid is removed from any further consideration.

Items evaluated for additional functional contribution are those items called "desired items, features or other system requirements", which are functional characteristics sought by the procuring agency, unless they are too costly. These "other system requirements" are normally items required for a user's system, but are items which might possibly be obtained from other sources, performed in-house, or what's most likely, simply done without at some sacrifice to meeting full user needs.

In any case, the failure of a bidder to offer the "other desired items" indicates possible additional expenditures to the procuring agency to compensate for the absence of the feature(s). The predetermination of the potential additional expenditures for these desirable characteristics represents the "worth" of the items to the user and is expressed in a value matrix in the IFB.

The necessity for establishing a dollar value for all "desired items" is to make dollars the common denominator between evaluated items and determining a systems "life cost".

> "Using a computer purchase as an example, while it might be easy to say that a "115 nanosecond add time" would be desirable, it may be totally impossible to determine a realistic dollar worth for that feature. The inability to place a dollar value on an item indicates that the wrong feature is being considered. For example, the "115 nanosecond add time" is not the important consideration. The important consideration is more likely to be the total time required to run a representative program (consisting of a large number of adds), together with a number of other representative programs, since that time, extended by an appropriate (pre-established) factor, results in the number of hours per month required by each system bid. However, even that time, and the one to which a dollar value can be assigned, is the time remaining (per month) after all the known and represented work load has been processed. The time remaining is the time available for expansion. The value of the expansion capability can be determined by considering the nature of the work load, the probability of the work load, the probability of the work load exceeding the time available to do it, the probable cost of equipment or rented service necessary to do the additional work load, etc."[33]

Similarly, the value of a software program offered by a bidder can be determined by considering the cost that can be avoided if the using agency does not have to write the program, buy it elsewhere, or operate without it. The value of an item should be the lowest cost alternative available to the using activity.

> "If the cost of manually flow charting is $45,000 and the cost of writing a flow charting program would be $32,000, but a flow charting program could be bought for $15,000, the value of the item is $15,000."[34]

Not only is it necessary to predetermine the dollar value for every "desired item" to be used in the evaluation,

> "it is also necessary to understand how the established dollar value(s) vary with time (is it $X per month or a one-time expenditure of $Y and, if so, when is that expenditure made?) With capability offered (if the flow charting program offered by a vendor is not as powerful as the one desired) would you: not consider it; or use it and do some conventional flow charting on Y + % of your programs; or etc? The pre-establishment of these variables is contained in a value or assessment matrix. A matrix should be established for every "other system requirement" used in the selection. This matrix showing the time value of all desired items must be disclosed to the vendors to help them bid."[35]

The least total cost technique considers not only the cost of the mandatory functions but of all features sought by the using agency. 1) System cost is calculated for mandatory equipment, software, support, etc. 2) Determinations are made for "other system requirements" if a bidder does provide an item, but at some cost which is less than its stated value, that lesser cost is subtracted from his bid. If no charge, then entire value is subtracted. 3) Then the "user costs" for expenses like power, staffing, etc., are calculated.

In this manner costs of meeting functional requirements over the stated system life are considered in the evaluation. The system having the least total cost calculated for the prescribed system life is the system that is selected.

The idealized approach presented here is based on the procurement of a complete system for aspects of a given system life cycle. The same technique would apply for acquisition of individual system elements such as plug-compatible direct access devices or for the acquisition of software packages. Even with individual system components, there are considerations in addition to the component price. Power requirements may differ, site prerequisites could cause expenditures over and above the amounts required for just the hardware. Software or operating system changes could prove to be costly and thus reduce an apparent cost advantage. Such costs should be evaluated over the system life cycle of the individual component or software package and considered in determining award.

Bidder strategy in responding to a "least cost" approach would be to determine marginal costs, compare to potential responses of other bidders and "rewards" calculated in value matrix. In this way, innovation and a competitive character should pervade bidder decision-making.

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The objectivity of evaluation criteria for user costs should be based on easily verifiable characteristics, e.g. power, staffing, materials, space, etc. The value for desired characteristics should also be based on verifiable characteristics, e.g. net time to accomplish needs. Any weighting among characteristics should be determined in advance and made a part of the bid solicitation so all bidders know the basis for award determination.

EXAMPLE II

Outline of Award Determination Considerations[36]

Objective: Use of IFB for purchase/least of computer system and components, support services, manuals, maintenance services on a least cost basis.

Issues

1. Establish purchase description (called system hardware and software "specification")

a. Make needs analysis (this is a disciplined requirements determination process, the procedures for which are given in "computer procurement guidelines")[37]

b. Establish required functional capabilities to meet needs (part of the requirements determination process accomplished by in-house technical staff, utilizing supplemental resources as indicated below)

User input: a policy advisory committee, composed of the prospective major users of the system, review the required capabilities to be sure that they net out ot meet the potential users actual needs.

Current data processing installation managers: a review committee of managers of data processing installations is selected on the basis that their installations utilize equipment manufactured by potential bidders on the subject IFB. These managers have a practical working experience for reviewing the content of an IFB, especially as regards source selection criteria.

Possible variation: a "rough-cut" purchase description could be issued to industry as the basis for a pre-solicitation conference; refinements to this rough-cut could be the result of exchanges in a pre-bid conference; this technique could contribute to a revised needs concept, either increasing or modifying the initial purchase description.

Basic Premise: reliance on the private sector as the source for meeting government needs means that a "competitive process" is implicitly underway when the government enters the commercial market place. One of the benefits to be derived by the government from this on-going competition is to measure its own capabilities and understanding against what is available and thus tailor government functional requirements determination based on the broadest technology base. Functional purchase

descriptions should be written with minimum constraints to elicit maximum competition. On the other hand, there is no reason why government must seek the lowest common denominator of "needs statement" just to guarantee a large number of bidders. The government ought to be able to specify its functional needs based on a full understanding of what exists in the technology base.

2. Maximizing product competition and enhancing bidder understanding

   a. Use of bidders conference - to provide clarification of items contained in IFB; (could utilize, in part, to describe anticipated variations in computer use environment to elicit response or observations from prospective bidders); all pre-bid conference proceedings recorded, transcribed, summarized and distributed to all prospective bidders.

   b. Interpretations – binding on government only if set forth in writing; text of requests and interpretations sent to all prospective bidders.

   c. Details of system - each deliverable component listed separately in IFB response to clarify system content.

   d. System demonstration - requirements of IFB give government option to require demonstration to verify performance or compare competing systems during bid evaluation.

   e. Questions section - in order to be responsive, bidder must answer an extensive list of questions, to be used as an aid in evaluation of bids (neither questions nor responses are used in contract document).

3. Creating opportunity for innovation in bidder responses

   a. Alternatives to system hardware and software purchase description (specifications) invited:

   Provided:

   Bidder first has been responsive and fully complied with all requirements in basic IFB

   Bidder alternatives not subject to any negotiation

   Alternatives considered in determining "best bid" for purposes of making contract award

   b. Modifications (Amendments and/or additions to bid invited for): Form of bid (Price & rate schedules, lease w/option to purchase, performance bonds, etc.)

   Deliverable items and performance requirements (Deliveries, warranty, licensed software, equipment maintenance services, etc.)

   Acceptable provisions (Demonstration of future capabilities, acceptance test period, standard of performance, etc.)

   General contract provisions (Definitions, insurance, equal opportunity, rights in data, taxes, invoices, and payments, risk of loss or

damage, survival of terms beyond expiration of agreement, etc.)

Provided:

Bidder must designation modifications as;

"required"

or

"desired"

Bidder must indicate cost impact for buyer excluding any bidder proposed revision

Buyer reserves the right to accept any or all modifications

4. Determining evaluation and award factors

a. Basis of determining costs: Total costs to procure, install and operate system (calculated for a seven year period)

Including:

Purchase price	Technical support services
Maintenance charges	Manuals
License charges, software	Monthly lease rentals
Maintenance fees, software	Conversion costs
Rental, program product	Training

Any additional cost adjustment to insure that total costs to utilize the system for a 7 year period are considered

b. Basis of award: Major consideration given to lowest total cost to utilize hardware & software

Other factors (desirable characteristics) of major importance:

interface, exchange, flexibility considerations; efficiency & simplicity of data management concept; ability to expand for out-year applications.

Possible variation: a matrix of values for desirable characteristics could be established, including associated dollars, expressed in the IFB as detailed in least cost example above; other items could be included in a "question section"; together these would eliminate or minimize controversies over undifferentiated "major considerations", other than bid price, being used as evaluation criteria and would have the effect of converting qualitative considerations into measurable dollar differences.

CONCLUSION

The rigidity and costs associated with formal Government specifications may not serve the best interests of the Government from the standpoint of meeting actual user needs or achieving lowest ultimate cost.

This paper has suggested one conceptual alternative to such problems through the use of functional purchase descriptions and award determination procedures which involve qualitative judgements and user cost considerations.

Award determinations based on innovative, competitive proposals and their related cost implications, argue for a new way of looking at formal advertising. This new standard is ultimate costs related to a product and its characteristics rather than a narrow concept of initial bid price as the basis for award.

Simply stated, this is product competition rather than initial bid price competition.

Use of functional purchase descriptions is only relevant to situations where there is a strong private sector technology base to serve particular government needs.

The references cited represent complex and time-consuming examples of some of the basic principles involved in the use of functional purchase descriptions. The purpose of citing such complex examples is to require consideration of the maximum number of variables. The basic principles should survive these complex examples for routine use in much simpler procurements.

Despite the complexity of the ADPE examples, the buyer was in a position to evaluate a member of competing and innovative approaches. Options were afforded to bidders which in turn gave the buyer a qualitative choice in determining which combination of factors best met actual needs for the lowest ultimate cost.

The past history of Comptroller General decisions on related purchase description issues has established concepts of valid purchase description, actual needs and salient characteristics, all of which appear to be adaptable to guide the use of functional purchase descriptions in sealed bid proceedings.

It appears that the government often may avoid the costs of developing and administering formal government specifications for many products, while affording itself the opportunity of considering the latest technology and innovative approaches in meeting government needs at the lowest possible cost.

Footnotes

1 Federal Acquisition Act of 1977, Senate Bill S.1264; 95th Congress, 1st Session.

2 Comp. Gen. Dec. 17:554:560, Jan. 8, 1938; C.G.D. B-157053, Aug. 2, 1965; C.G.D. B-169140, July 8, 1970; as cited in Report of Commission on Government Procurement (COGP), vol. 3, p. 15.

3 COGP vol. 3, p. 15.

4 Ibid, p. 16.

5 See Government Contract Bidding by Paul A. Shnitzer, Associate General Counsel, GAO; Federal Publications, 1977; The definitive work on bidding concerns including specifications.

6 COGP vol. 3, p. 19.

7 Ibid, p. 20.

8 Ibid, p. 20

9 ASPR 1-1206.1.

10 C.G.D. B-161704, Sept. 26, 1967.

11 C.G.D. B-162475, Mar. 19, 1968.

12 The policy for reliance on the private sector, OMB Circular A-76, is currently under review by the Office of Federal Procurement Policy.

13 34 Comp. Gen. 336; 45 id. 365 (cited in C.G.D. B-162475, Mar. 19, 1968).

14 C.G.D. B-161118, June 1, 1967.

15 33 Comp. Gen. 573.

16 C.G.D. B-116236, Dec. 5, 1955.

17 Ibid.

18 FPR 1-1.307-4; ASPR 2-202.5.

19 41 Comp. Gen. 242.250-251. See also C.G.D. B-157857, June 26, 1966, cited in 48 Comp. Gen. 441 (1968); 49 Comp. Gen. 247 (1969); C.G.D. B-173290, Oct. 19, 1971; referenced in C.G.D. B-175955, July 25, 1972.

20 Sample extracts of Purchase Description:

7.0 <u>SYSTEM HARDWARE AND SOFTWARE SPECIFICATIONS</u>

7.1 <u>OVERALL SYSTEM REQUIREMENTS</u>

7.1.1 <u>General Capabilities</u>

The proposed computer System must include the necessary Hardware, Software and related support services, which have the capability to meet the requirements of this Agreement and to perform the following types of processing concurrently as they are defined in Section 11.1:

A. Time Sharing;

B. On-Line Transactions Processing;

C. Remote Batch Job Entry; and

D. Local Batch Processing.

7.1.2 <u>Physical Limitations</u>

The computer System with peripheral equipment as initially contracted for must operate within the following physical limitations: PHYSICAL LIMITATIONS: an area 21 feet by 36 feet. The layout of equipment in the 21' x 36' area must allow sufficient space for all necessary maintenance and operation. If additional space is required, this must be clearly stated in the Bid under this section. ...

7.1.8 <u>Privacy and Security</u> - The Bidder should specify the security and privacy capabilities of the computer System in the modes indicated in Subsection 7.1.1. It is expected that these capabilities will be reasonable in light of the state of the art and the protection provided to the right of privacy as specified in the California Constitution. ...

21 C.G.D. B-165409, Dec. 26, 1968.

22 ASPR 2-202.5 (d) (i); FPR 1-1.307-4.

23 C.G.D. B-161122, May 11, 1967.

24 41 Comp. Gen. 366

25 30 Comp. Gen. 368

26 45 Comp. Gen 312, 316 (1965); 41 id. 366 (1961); cited in C.G.D. B-169482, Sept. 16, 1970.

27 C.G.D. B-177229, Feb. 8, 1973.

28 "Least Cost" approach will be amplified in examples below. It involves the quantification and consideration of anticipated costs as well as bid costs.

29 COGP vol. 3, p. 45.

30 Ibid.

31 Models used in this paper are based on Computer Hardware Procurement and Contracting Guidelines of the Intergovernmental Board of Electronic Data Processing, 1025 P Street, Sacramento, CA 95814.

32 The terminology "least cost" and the example are modeled on the approach given in the Guidelines cited in 31 above.

33 Guidelines, p. 37.

34 Guidelines, p. 38.

35 Guidelines. p. 38.

36 This case was supplied by Central Valley Educational Data Processing Center, Fresno, CA 93721.

37 Cited in 31 above.

THE FOUR STEP SOURCE SELECTION PROCEDURE AND TEST

LTC Douglas C. Dillon, USAF
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OASD(MRA&L)

LTC Dillon spoke extemporaneously on his subject and did not submit a paper per se. The following abstract and charts should give an idea of his talk.

The revised DOD Directive 4105.62 dated 6 January 1976 is the top DOD document on selection of contractual sources for major defense systems; it covers, among other things, the source selection authority responsibilities and organization, solicitation preparation, and evaluation. A major concept introduced here is the 4-step source selection procedures and its objectives. An evaluation of the 4-step test program has recently been completed and comments on preliminary test results and trends can now be made.

(See attached charts and explanations)

This chart reflects assessment areas being used by the DoD Evaluation Group. Of particular importance in the second item is the word "may". It is nearly impossible to say with any degree of confidence that technical leveling, auctioning and buy-ins actually occurred on any given program. We do however hope to identify conditions or circumstances that may lead to or indicate these things could happen.

ASSESSMENT AREAS

- **IDENTIFY METHODS AND PROCEDURES TO IMPROVE SOURCE SELECTION PROCESS**
- **IDENTIFY CONDITIONS AND CIRCUMSTANCES THAT MAY LEAD TO OR INDICATE:**
  1) TECHNICAL LEVELING
  2) AUCTIONING
  3) BUY-INS

The initial DoD Directive 4105.62 was issued in 1965. Around 1970 then SecDef Packard was concerned about how we select our contractors for major weapon systems. One of the results of his concerns was the issuance of DoD Directive 5000.1. With the issuance of this directive, it was recognized that DoD 4105.62 required revision and updating.

Also during this time there was considerable emphasis within the DoD to implement the 4-step procedures. It was decided by the DoD that with the issuance of the new Directive 4105.62 dated 6 Jan 1976 the new 4-step procedure would be tested. It was thought by some quarters that the proposed 4-step procedure would alleviate these assertions by industry and the government.

This chart shows the criteria currently being used by the DoD Evaluation Group against which program data is measured. Notice the major headings correspond to a previous chart entitled Test Purpose.

CRITERIA

IMPROVE SOURCE SELECTION

TIME
SOLICITATION QUALITY
PROPOSAL QUALITY
PERSONNEL UTILIZATION
SOLE SOURCE/MULTIPLE NEGOTIATION
PROTEST ACTIVITY

TECHNICAL LEVELING

DEFICIENCY DISCUSSIONS
MULTIPLE SCORING
REPETITIVE SCORING
RFP AMENDMENTS

AUCTIONING

BEST AND FINAL OFFERS
HPA WAIVERS

BUY-INS

COST ESTIMATES
PROPOSAL REDUCTIONS
PROPOSAL INCREASES

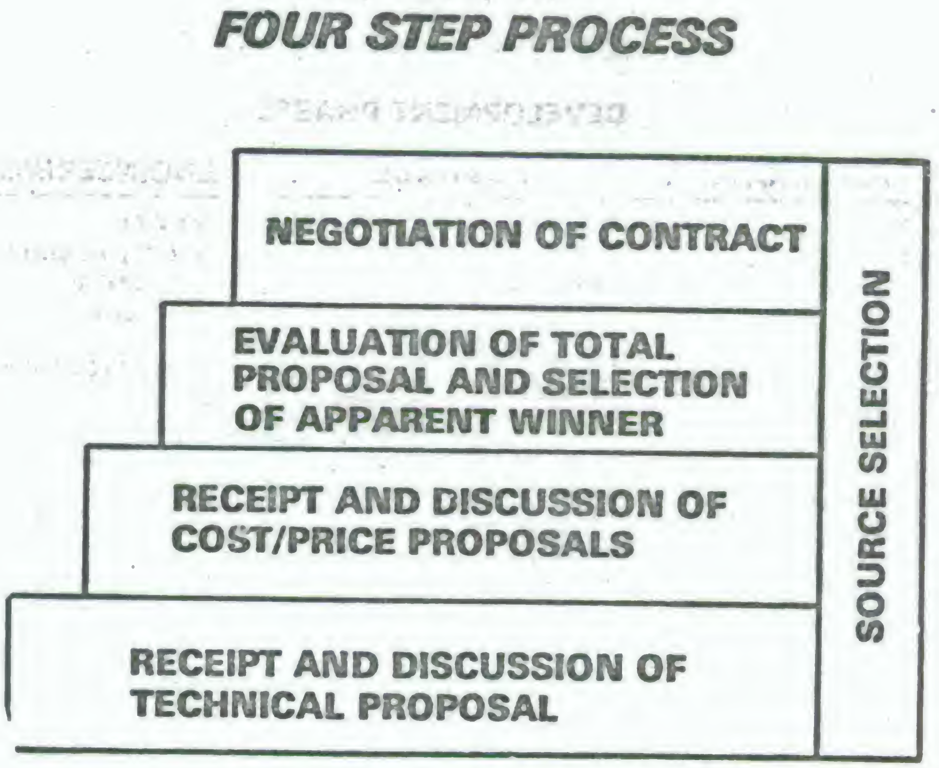
This chart depicts those programs currently identified as 4-step test programs, and the development phase each program is currently experiencing.

TEST PROGRAMS

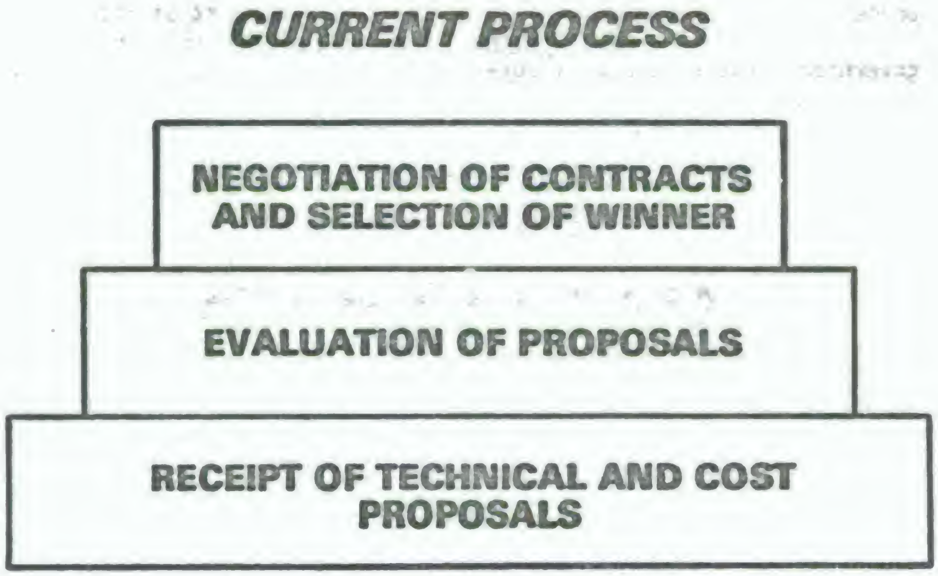
DEVELOPMENT PHASES

EXPLORATORY	ADVANCED	ENGINEERING
• JTIDS	• SUB/AIR COMM SYSTEM	• SOFT RAG
• ENGINE, 800HP	• FLIR SENSOR	• ROCKET LAUNCHER
	• ECHO RANGE TRANSMITTER	• LAMPS-MK III
	• MARK/GUN LASER	• SPS-10 RADAR
	• ASW PODS	• SAWS
	• IUS	• B52/KC-135 SIMULATOR
		• SATIN IV
		• JSS
		• INVERTER-3KW

This chart represents the 4-step process as currently being tested. Notice that the lower step of the current process has now been broken out into two steps.



As a matter of reference, this chart depicts the current procedure used by the DoD in selecting its contractual sources.



The purpose of the 4-step test program is to improve the quality of our overall source selection process and to eliminate or reduce program, technical leveling, buy-ins and auctioning. There have been accusations by industry that the government indulged in technical leveling and auctioning during the source selection process. Similarly, there are accusations on the part of the government that contractors buy-in.

TEST PURPOSE

- IMPROVE QUALITY OF SOURCE SELECTION PROCESS
- TO ELIMINATE OR REDUCE PROGRAM
  - TECHNICAL LEVELING
  - BUY-INS
  - AUCTIONING

The source selection objectives of the DoD have not changed with the issuance of the new directive. This chart reflects the current objectives.

SOURCE SELECTION OBJECTIVES

- HIGHEST DEGREE OF REALISM AND CREDIBILITY
- PERFORMANCE MEETS GOVERNMENT OBJECTIVES
- AFFORDABLE COST
- ASSURE IMPARTIAL, EQUITABLE, COMPREHENSIVE EVALUATION
- MAXIMIZE EFFICIENCY
- MINIMIZE COMPLEXITY

The source selection authority responsibilities remain as shown on this chart. These responsibilities have not changed as a result of the new DoD directive.

S.S. AUTHORITY

- CONDUCT PROCESS
- SELECT SOURCES
- DCP/SECDEF MEMO
- SELECTION RESULTS

The new DoD Directive 4105.62 does make some changes to the source selection process. However, there are some things that remain unchanged as shown on this chart.

UNCHANGED ASPECTS

- SOURCE SELECTION OBJECTIVES
- SOURCE SELECTION AUTHORITY
- SOURCE SELECTION ORGANIZATION

As we envision at the current time, the test results will dictate a decision on the part of the DepSecDef as represented by this chart.

TEST RESULTS

MANDATORY USE

USE WHEN APPROPRIATE

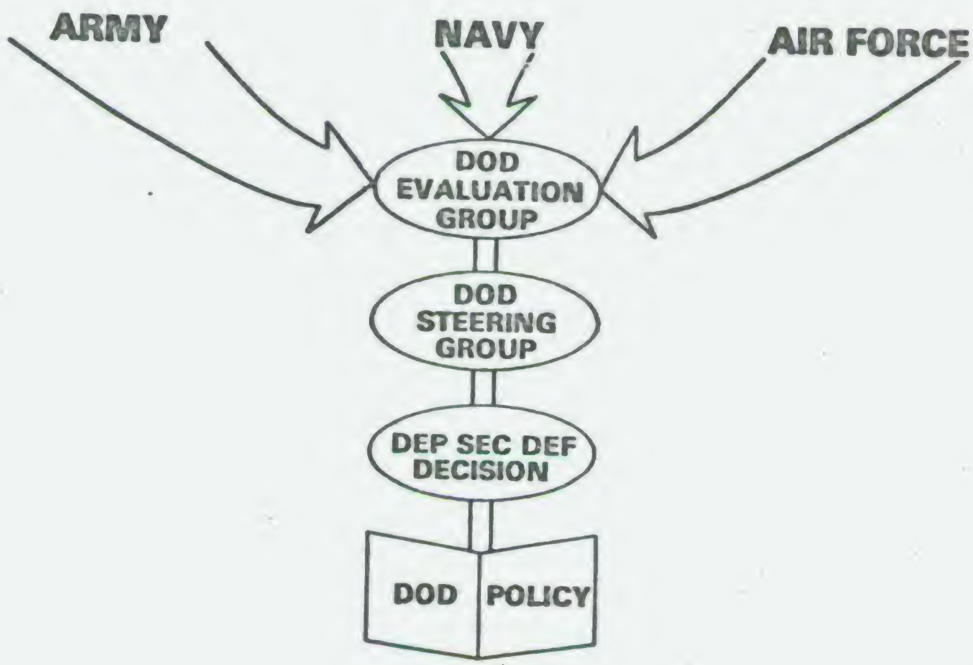
DO NOT USE

MAKE APPROPRIATE CHANGES TO DIRECTIVES

This chart depicts the vertical organization for testing the 4-step process. Data is received from the three Service components by the Department of Defense Evaluation Group. This Evaluation Group is the working organization actually reviewing the data.

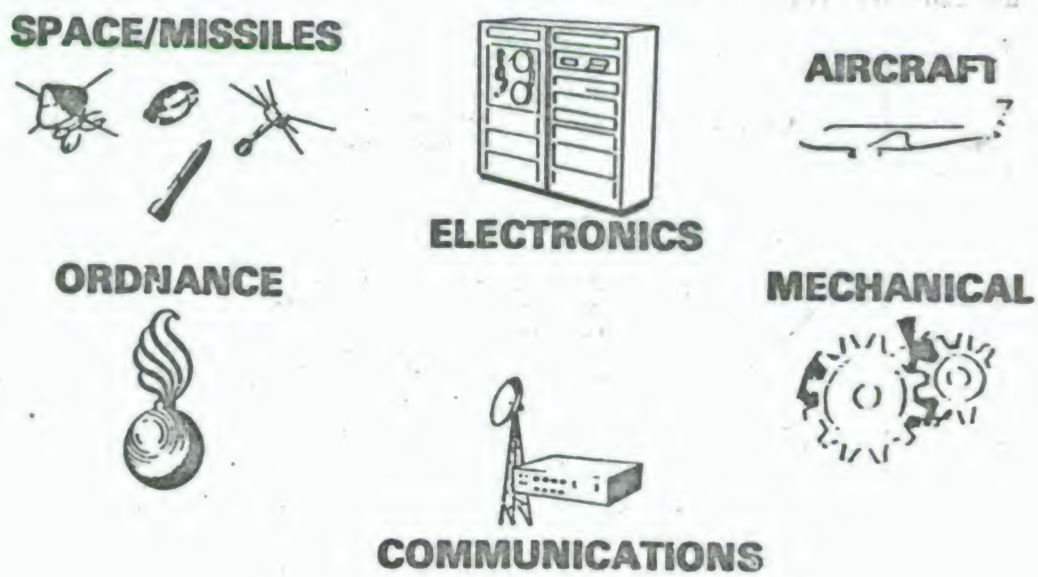
The DoD Steering Group is an advisory body to the DoD Evaluation Group. In addition, at the completion of the test, they will make a recommendation on the adoption or rejection of the 4-step to the DepSecDef. His decision will result in DoD policy.

EVALUATION PROCESS



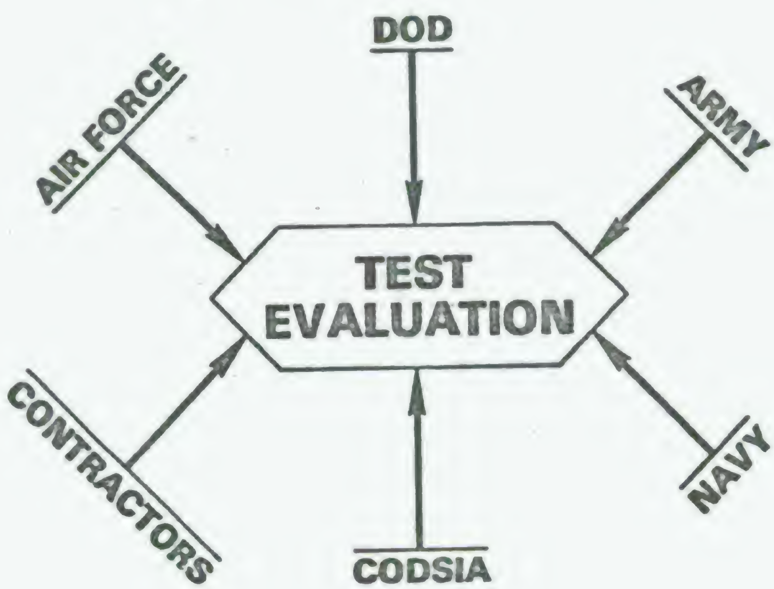
This chart represents the various types of programs included in the 4-step test.

TYPES OF PROGRAMS



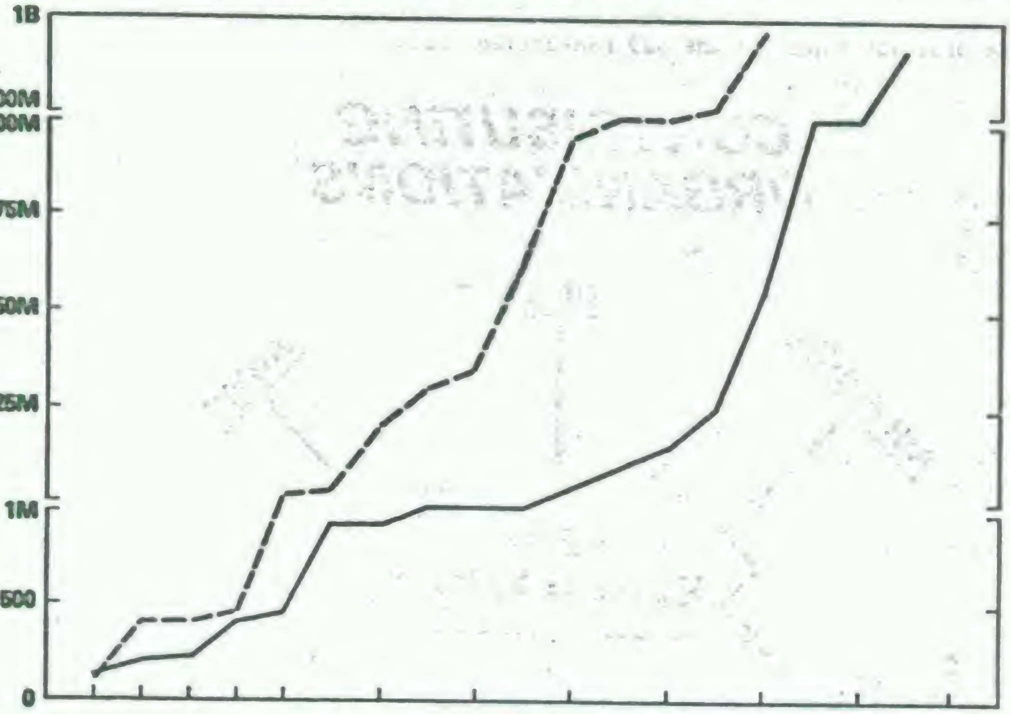
This chart represents those organizations participating in the test of the 4-step source selection process. The term contractors represents those contractors who are participants in one of the 4-step candidate programs. CODSIA is an organization whereby those firms who did not participate in a test program due to product line or some other reason may have a means to make an input to the evaluation of the 4-step process. Near the end of the test, CODSIA will submit a position paper to the DoD Evaluation Group.

CONTRIBUTING ORGANIZATIONS



Dollar values of test programs range from $100,000 to over $1 billion represented by the dotted line. The wide range of program values is proving to be very beneficial.

PROGRAMS DOLLAR RANGE



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SOURCE SELECTION RESEARCH - IS ANYBODY INTERESTED?

LtCol F. Theodore Helmer
Associate Professor of Management
US Air Force Academy

Before I begin this discussion, let me say that I solicit your feedback and reactions to my comments. My brief remarks will further emphasize the need for translating procurement research into action--the major theme of this symposium. My sincere concern for translating research results into application is the sole reason I accepted Bob Williams' invitation to address this distinguished group. I want to share with you my frustrations as a procurement researcher in getting the attention of the "system" in my attempts to make change rather than to just publish a research paper for academic and officer performance report credit.

In particular, I will discuss two source selection research projects that have caused this frustration. I hope the output of this symposium will help minimize this frustration for future researchers in this area. After hearing General Stansberry yesterday, I have begun to wonder if my two experiences fall into the category of non-problems. If so, you may disregard my remarks totally and enjoy the view. If not, then I hope that we all leave West Point with a greater knowledge of how research should have some impact upon the system.

Let's get back to the topic of source selection research. Last year, this group honored Major Bob Taylor and me with one of the NCMA awards for our paper, "A Conceptual Model for Management Evaluation During Source Selection." We have printed over 400 copies of this report and have about 25 left. We made an initial distribution of about 100 to libraries, buying agencies, DLSIE, etc., throughout the Department of Defense. Upon request, I recently presented that paper at the National Convention of the American Institute of Industrial Engineers. I had a room capacity crowd. Perhaps more significant, however, is the fact that we mailed out over 200 copies at the specific telephone or written request of people in the field who are involved in source selection in several governmental agencies and in subcontractor selection. The positive response of most of these requestors has been the same--they consistently ask, "Why didn't I learn of your research sooner?" (i.e., before we sent out our RFP) and, "When will DOD react to your ideas and modify source selection procedures?" You can readily see our frustration--we can't answer these questions. I don't mean to imply that our research is the greatest thing since sliced bread, but it does suggest a different way of attacking one aspect of source selections, and the feedback from procurement practitioners has been overwhelmingly positive. We have received no response from higher headquarters, except one of our telephone inquiries was answered by the comment that "we tried that once a long time ago and it won't work."

Perhaps some insight into the origins of this research will help you understand our frustration. About two years ago, I was asked to head the management panel during the source selection of a major satellite program. I arrived in Los Angeles about the time the proposals did, formed a team, and started comparing apples, oranges, bananas and peaches. There was nothing in the literature or DOD publications to help us, and I was so frustrated by this experience and the shallowness of my recommendations that I began this research topic with Bob Taylor. We visited numerous DOD contractors to learn how they evaluated their major subcontractors during source selection. This input, plus interviews with members of previous Air Force source selections, resulted in our research report.

I sincerely believe we have some good ideas, yet the "system" seems to ignore our efforts. Positive feedback from members of all three services has been our only reward, and does indicate to us that our suggestions are being used. Please remember that this research was total unsponsored--we just saw the need to improve and tried to make a contribution.

My second attempt at unsolicited source selection research came as the result of some research I was doing with the RAND Corporation. I was working on the optimal future utilization of certain conceptualized aircraft, and we developed a complex computerized O.R. model designed to minimize life-cycle costs and maximize mission effectiveness. As it turned out, this model had immediate application in the evaluation of several alternative aircraft then undergoing source selection. With the input of only (1) the mission being evaluated, (2) the performance characteristics of each aircraft, and (3) the life-cycle costs per flying hour, our model would indicate which of several considered aircraft would be the most economical to procure in the long run. I hope you agree that such research has merit, but we could <u>not</u> sell the concept to the buying office which was deeply ingrossed in source selection activities.

As a former procurement officer, I fully appreciate their position, and if I were in their shoes, I would have had the same reaction from an unknown person making unsupported promises in an <u>untimely</u> manner to the solution of a politically volatile decision. As a researcher, however, I was again frustrated by the fact that our research results were so poorly timed that the SPO could not integrate them with their source selection efforts. This poor timing was unfortunate, but if we had a <u>sponsor</u> for this research we would have had little of the frustration.

It is extremely unfair to make charges against a system I have sworn to defend without making positive recommendations for its improvement. The Air Force Academy has made many contributions to procurement over the past several years. The only ones that have been extremely successful, however, are those efforts that had a sponsor--usually a general officer or high ranking civilian. These efforts were always translated into action by the sponsor, and we were involved in both the research and the implementation phases. Examples include PIECOST, PIEMAN, Project POL, Project EOQ, Procurement Quality, R&D Cost Prediction, etc. In our opinion, <u>unsponsored</u> procurement research conducted so far away from the real world of procurement has proven frustrating and non-rewarding. Does this imply that we should <u>not</u> look for problems and try to pose solutions? I sincerely believe that we must remain inquisitive to problems, but before we expend too much of our energy and enthusiasm, we must find a sponsor who is equally enthusiastic. This is extremely difficult for us at the Academy to accomplish as we have a travel-limiting teaching schedule and very small TDY budget.

My remarks this morning are meant to be constructive in nature, for we at the Academy have a strong desire to continue our research efforts in the procurement area. Being realists, however, we are not in a position to strongly <u>market</u> our efforts. Many of you in this room share this concern. Is there a way the unsponsored procurement research can be conducted without being a threat to people who are proponents of the established system? How should research results be communicated to the field? How can we improve the attitude towards source selection research by people in the field? How can source selection research be accomplished in a system that may have overriding political considerations? Must we have a sponsor? I sincerely hope that the dialogue we have today will help all of us accomplish what we so dearly want to do--constantly improve our procurement system.

EPILOGUE: Immediately after these comments were made at the sympoisum, I received two very sincere offers to allow us to further test our management evaluation model during two future source selections. In addition, I made contact with the procurement officer of the program office involved in the referenced aircraft source selection. He invited us to provide him with information about our model, and I am satisfied that our research will get the attention it should. The frustration mentioned during this talk has been alleviated because of the participation of sincere, educated procurement executives who truly desire to improve our procurement system. I am convinced that active and aggressive marketing and communication of research projects is the key to their successful implementation. For us, this 6th Annual DOD Procurement Research Symposium with the topic, "Translating Procurement Research Into Action" has been a complete success.

IMPROVING THE SOURCE SELECTION PROCESS

BY MEASURING THE HUMAN RESPONSE OF PROPOSAL EVALUATORS

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ABSTRACT

First, data is presented from the Evaluator Preference Survey where attitudes and evaluative judgement of a quasi-random sample of 33 experienced DoD technical proposal evaluators were measured. This data indicated that government personnel have very favorable attitudes toward proposal evaluations. Strong agreement was shown that evaluations are interesting, hard work, but worthwhile for the government. However, other Survey data indicated considerable room for the government to improve proposal evaluation mechanics. Most evaluators indicated they reinterpreted scored evaluation criteria. There was only moderate judgement that scored evaluation criteria and rating scales were "good" and "fair."

It is suggested that the government improve the proposal evaluation aspect of source selection by conducting experimental research. The experiments would consist of having groups of experienced evaluators score experimental and real-world proposal material. This research would improve evaluation rating scales, evaluation criteria for scoring, determine preferred evaluation mechanics, and improve scoring discrimination.

Feasibility of the proposed research methods is demonstrated in experiments previously conducted by the author. An experiment is described where the same experimental proposal material was scored using seven different rating scales. Preliminary data is presented for scoring differences using a truncated versus linear adjective-numeric rating scale. It was found that the linear scale gave greatest discrimination between evaluation scores--a result exactly opposite to commonly held government belief. Scores were compared between Navy used relative rank scoring and Army and Air Force preferred adjective-numeric scoring. Relative rank scoring was found superior in forcing discrimination. A proposal scoring difficulty was also uncovered. Direct readbacks of the Statement-of-Work consistently scored near average over all rating scales that were examined.

End product of the proposed experimental research would be a proposal evaluation guide that defines a preferred rating scale, and directs the evaluators in how to make their evaluation scorings. Such a guide would improve the quality and discrimination of proposal evaluation scores, and attest to the practical value of applied procurement research.

INTRODUCTION

During the past four years I have been conducting empirical research on the human response of experienced government evaluators to experimental proposal material. The main purpose of this research has been to improve contractor proposals submitted to the federal government. The main vehicle for doing this has been presentation of the research results at my public seminars "How to Improve the Evaluation Score of Your Technical Proposals."

The purpose of this paper is to show how the same experimental methodology can be used by the government to improve the proposal evaluation phase of the source selection process. Suggestions for specific research will be made, and feasibility of the methodology demonstrated by presenting some experimental results from my previous studies.

GROUNDRULES AND DEFINITIONS

To establish a common base of understanding some definitions need to be made. First, we will be concerned with the evaluation of technical proposals. These are considered to contain both technical and management discussions. The technical proposals are usually rated or "scored" by evaluators against a set of established evaluation factors. Because of the diversity in the use of such terms as evaluation criteria, evaluation factors, sub-factors, etc., "evaluation questions" are defined to be the actual items against which the proposals are scored. "Evaluation criteria" are defined to be the stated basis on which the proposals are scored. These appear in the solicitation and are usually referred to there as "evaluation criteria" or "award factors."

Rating methods have been examined by psychologists in some detail, References 1 and 2. There are four basic methods of rating: paired comparison, comparison with a set of examples which exemplify a range of the attributes being considered, rank order, and rating (numerically, by adjectives, or colors) on some standard scale. The rating methods used by the government for proposal evaluation have been almost exclusively rank order and rating scale.

The government's proposal rating scales can be placed into the following four general categories, or some combination of them:

NUMERIC The evaluator using this rating scale merely estimates on a predetermined numerical scale what he considers to be an appropriate score for each proposal on each evaluation question.

ADJECTIVE-NUMERIC This rating scale ties qualitative adjectives to numeric rating scale scores. This helps calibrate the same numerical scores to the same evaluative judgement. Often the adjectives contain additional amplifying definitions.

Adjective-numeric rating scales are often truncated. That is, the numerical scale is not linear, but instead contains a large scoring penalty for extremely low quality proposals. With truncated scales responses that are marginally acceptable may score forty or fifty percent of the total scale score while "Unacceptable" responses score nothing. Many government people feel that truncation produces the widest separation of total evaluation scores--an obvious benefit to the government.

CHECKOFF With this rating scale the evaluation questions receive only one of two possible scores, usually "Acceptable" or "Unacceptable." This rating scale is often used in evaluating technical proposals submitted in Step One of Two-Step procurements where it is only necessary to determine that the proposal is technically acceptable.

ADJECTIVE On this rating scale a proposal receives one of a set of adjective ratings on each evaluation question. The adjectives may also include definitions to help calibrate scores. Recently, color codings have been widely used in place of adjectives. Adjectives or colors cannot be combined. If it is necessary to combine scores then numerical equivalents are assigned, and the method reverts to an adjective-numeric rating scale.

RELATIVE RANK is also used to rate proposals. In relative rank scoring the evaluators rank each submitted proposal from best to poorest response on each evaluation question. Numerical scores can be assigned to each rank position. Relative rank is heavily used by the Navy, but not much outside of the Navy.

Adjective-numeric rating scales are predominantly used by the Air Force, Army, and NASA. The following rating scale usage was obtained from an analysis of about 35 proposal evaluations conducted by these agencies:

RATING SCALE	PERCENT OCCURRENCE
Checkoff	6
Adjective	12
Adjective-Numeric	59
Numeric	23

The sample contained about equal representation from the three agencies with fairly random distribution geographically and among technical disciplines. The sample is too small to accurately reflect the real occurrence rates, but is probably sufficient to show that adjective-numeric rating scales are predominently used in proposal evaluations up to a few million dollars by these agencies.

EVALUATOR ATTITUDES CONCERNING THE EVALUATION PROCESS

I recently completed an Evaluator Preference Survey (Reference 3) which measured attitudes and evaluative judgement of a quasi-random sample of 33 experienced DoD proposal evaluators. Included in the Survey questionnaire were two items concerning the evaluation process. These two items and the evaluators scorings are shown in Figure 1.

The evaluators evidenced very favorable attitudes toward proposal evaluations. The majority of the evaluators appeared to find proposal evaluations interesting and not boring. There was strong agreement that proposal evaluations are hard work, but are worthwhile for the government. These favorable attitudes might imply, or are in keeping with, diligence in evaluating proposals. It should be added that checks included in the questionnaire indicated that honest rather than "motherhood" responses were obtained in the survey.

Seven questionnaire items were included to probe evaluator pre-selection bias. The scores implied that 75 to 80 percent of the evaluators appeared to consider the submitted proposal more important than prior knowledge of the submitter. Consequently, one out of four or five evaluators evidenced strong pre-selection bias, i.e., prior knowledge of a submitter was more important than the submitted proposal.

EVALUATOR ATTITUDES CONCERNING PROPOSAL EVALUATION MECHANICS

Two items were included in the Survey questionnaire to measure attitudes toward the mechanics of the evaluation process. Scorings of these items are shown in Figure 2.

Apparently, there is considerable room for the government to improve its evaluation processes. Most evaluators indicated that they made some reinterpretation of the evaluation criteria (i.e., the things the evaluators actually scored--the evaluation questions). There was only a moderate judgement that the "evaluation questions" and rating scales were "good" and "fair."

SUGGESTED RESEARCH

A potentially powerful research tool is available to improve the quality of proposal evaluations. This tool is application of the methodology of experimental psychology to proposal communications. In essence, experimental and real-world proposal material would be scored by groups of experienced evaluators. By measuring the evaluators' responses the government could examine many things, for example:

1. By scoring the same proposal material with different

rating scales the government could determine preferred rating scales. Rating scales would be selected based on such things as greatest separation of total evaluation scores (discrimination) and inter-rater score dispersion (reliability).

2. Evaluation questions could be improved by scoring the same proposal material against alternate forms of an evaluation question. Preferred evaluation questions could be selected in terms of utility for discrimination and smallest dispersion.

3. Proposal material that presents scoring difficulties could be detected. Scoring guidelines could then be formulated to aid evaluators in scoring these problem areas.

4. Evaluation procedures could be improved by scoring the same proposal material under different procedural methodologies. For example, proposals could be independently scored with subsequent discussions and scoring changes allowed versus having the evaluators discuss the proposals together in a group.

This is only a partial list of the many questions that could be experimentally attacked. This suggested research appears very cost effective. That is, the experimentation would be relatively inexpensive, but could pay big dividends in improving the quality of proposal evaluation for source selection.

The intent of congress promulgated through laws and regulations is source selection based on the proposal most advantageous to the government. If the desire is honest and objective source selection then improved evaluation of proposals can be of great help. If the desire is minimization of such things as contract award protests, then the proposed research may appear unnecessary. It should be noted, however, that minimization of award protests has not been established by congress as a procurement objective. Also, recent non-numerical scoring of proposals (e.g., color coding) has greatly increased contractor suspicions of dishonesty. Cynicism on the part of the contracting community can have strong adverse effects for the government that far outweigh defending a few protests.

EXPERIMENT DESCRIPTION

I have conducted some preliminary experimental studies which demonstrate the feasibility of the proposed research. The subjects in the experiments were participants at my public seminars. During the seminars the subjects were provided a typed four page Case Study. The Case Study asked the subjects to assume that they were government employees assigned to a technical evaluation committee on a $200,000 test program procurement. The subjects were then asked to score five hypothetical contractor proposal responses against the following evaluation question: "Has the contractor provided adequate photographic support for the test program?"

The five proposal discussions responded to the following Statement-of-Work item: "During conduct of the tests, the contractor shall provide high speed motion picture coverage of the tests (black and white, 16mm film at 200 frames per second). These films will be provided to the cognizant DCAS technical representative within two weeks following each test."

The five proposal responses to this Statement-of-Work item were structured to represent typical approaches often used in proposals. They may be summarized as follows:

Contractor A's response was a direct readback of the Statement-of-Work.

Contractor B proposed to paint the test item according to a multicolor code; and photograph the tests with color film, "to illustrate the actual test effects." The type of film was specified. Compliance was indicated to filming at 200 frames per second, and delivering the film within two weeks to the DCAS representative.

It was originally intended that this response would represent a "gold-plating" approach. That is, the requirement was for black and white, but the contractor was going to provide something above the minimum requirement, namely, color film at an implied increase in cost. However, a second legitimate interpretation of this proposal response was also encountered. The color film may not be technically acceptable. For example, color film at 200 frames per second does not provide the same resolution as black and white film. Consequently, color film might not be technically acceptable if resolution is important.

Contractor C's proposal was intended to be a good response. The contractor indicated *how* he would perform the work by indicating camera mounting and film processing arrangements. In addition, he gave the government a cost-free 3-day turn-around time on film delivered to the DCAS representative, and concurred that the photographic coverage was a necessary requirement based on his previous testing experience.

Contractor D used a give-us-the-money-and-we-will-do-whatever-you-want approach. He proposed to, "provide high speed motion picture coverage of each test, and provide the film to the DCAS representative within the required two week period," and to, "fully cooperate with the government to fill any photographic needs that may arise."

Contractor E's response was considered to be a good "how" response. The constractor indicated how the cameras would be mounted and the film processed.

VARIATION OF RATING SCALES

The five proposal approaches were scored by different groups of subjects using different rating scales. Although extraneous variables were not strongly controlled in these experiments the data was sufficient to serve the purpose of a preliminary study. The following seven rating scales were examined:

Group 1 used the truncated adjective-numeric rating scale shown in Figure 3. This rating scale was an adaptation of one recommended in Reference 4 for use by the Army.

Group 2 used the same adjective-numeric rating scale as Group 1, only the numerical scores were changed to a linear scale. Under this change Excellent was 100, Very Good was 83, Good was 67, Average was 50, Fair was 33, Poor was 17, and Unacceptable was zero.

Group 3 scored the proposal responses by relative ranking the submissions from 1 (best) to 5 (worst).

Group 4 used the experimental rating scale shown in Figure 4.

Group 5 used a set of semantic differential scales I wanted to test. The semantic differential was developed by Osgood, Reference 5, and is widely used by psychologists in attitude and other studies. It appears adaptable to proposals, but has not been used. The subjects using this rating scale were asked to rate the "Photographic Support of Test Program" on a 7 point continuum between opposite adjective poles. The opposite poles used were: inadequate-adequate, bad-good, and hazy-clear.

Group 6 scored the proposal submissions on a semantic differential scale using only the poles "adequate" and "inadequate."

Group 7 scored the five proposal submissions on a semantic differential scale with poles of "good" and "bad."

To date, data has been analyzed partially only for the first three groups. However, some interesting results have emerged from this limited preliminary data analysis.

First, the truncated rating scale compressed the evaluation scores relative to the linear rating scale--a result contradicting the reason given for using truncation. This can be seen from the mean scores of Groups 1 and 2 shown in Figure 5. The range from highest to lowest score using the truncated rating scale was 54.7. This compares to a range of 64.3 using the linear scale.

Second, the linear scale was superior to the truncated scale in other aspects of discrimination.

A. The linear scale was superior in separating the scores

of the "good" proposal responses, C and E, from the two "poor" responses, B and D. The separation between responses E and B, the weakest of the "good" and the strongest of the "poor" was 46.1 using the truncated scale. However, on the linear scale this separation increased to 53.6.

B. Better discrimination was obtained between the two best responses, C and E, when the linear scale was used. However, this last discrimination may not really be significant. Duncan's Range Tests were run between the mean scores of each group. The tests showed that the differences between all mean scores of Group 1 were statistically significant at the five percent probability level except between C and E. In Group 2 the differences between all mean scores were statistically significant except between B and D, and again between C and E.

In this experiment the government's objectives of greater separation of evaluation scores, better discrimination between proposals in the competitive zone versus those not in the competitive zone, and better discrimination among proposals in the competitive zone were better achieved with the linear rather than the truncated rating scale. More study of rating scale truncation appears warranted. Recommended additional study would include scoring real-world proposals by evaluators using linear versus truncated rating scales.

COMPARISON OF ADJECTIVE-NUMERIC TO RELATIVE RANK SCORING

Relative rank scoring was compared to adjective-numeric scoring. To do this, the adjective-numeric scores of Groups 1 and 2 were converted to relative rank scores based on the decending order of each subject's numerical scores. Relative rankings were not determined in cases where subjects scored two or more responses numerically the same. After deletion of these cases, 28 relative rank scorings were derived for Group 1, and 26 relative rank scorings were derived for Group 2.

Analysis of the rank data showed no statistically significant differences between the rankings of Groups 1 and 2 versus Group 3. This analysis consisted of conducting Duncan's Range Tests between the means of the three different groups on each proposal response. There were no differences that were significant at the five percent probability level.

One potentially important difference between relative rank and adjective-numeric scoring was observed. A large percentage of the subjects rated two or more of the responses the same when they employed adjective-numeric scoring. About half the subjects in Group 1, 27 out of 55, scored two or more responses the same. In Group 2, 11 out of 37 subjects, 30 percent, scored two or more of the responses the same. This compares to only 3 of the 54 subjects, 6 percent, in Group 3 that were unable to relative rank the proposal responses differently. Consequently, relative rank scoring may be superior to adjective-numeric scoring in discrimination.

Relative rank scoring has one inherent weakness. The evaluator is asked to make relative evaluative judgements. With relative judgements one proposal submission will always rank first regardless of how "poor" all the submissions are, and one will always rank last regardless of how "good" all the proposals may be. In general, ranking provides the least information because one can obtain identical sets of rankings for proposals which are quite similar and proposals that are extremely different.

The best approach might be a rating scale that asks the evaluators to consciously make both absolute and relative evaluative judgements. This kind of rating scale could be experimentally developed, and would require giving directions to the evaluators on its use.

DETECTION OF SCORING DIFFICULTIES

The preliminary experimental work has surfaced an example of a proposal scoring difficulty. My personal feeling is that readbacks of the Statement-of-Work are very poor responses, and should receive a low score (except for small inconsequential requirements). The Statement-of-Work should describe "what" is to be done. The proposal should tell the government "how" the program requirements will be met. Statement-of-Work readbacks do not describe "how" the requirements will be met and should, in my opinion, score very low.

It was my observation that readbacks on the Statement-of-Work usually scored about average in evaluations that I participated in as a government employee. The experimental work has confirmed this observation. Data on scorings of direct readbacks of the Statement-of-Work are presented in Figure 6. The Mock Proposal data points are from an experiment where I had 29 experienced government evaluators score two competing mock proposals. Additional descriptions of these experiments can be found in References 6 and 7. The important point to note is that direct readbacks of the Statement-of-Work consistently had mean scores near average, however "Average" was defined on the rating scale.

END PRODUCT APPLICATION OF THE PROPOSED RESEARCH

It is envisioned that the useful application of the suggested research would be improved evaluation questions and a short evaluation guide. The evaluation guide would instruct evaluators on how to score the proposal material. The rating scale would be presented, and its operation described. Applicable procurement regulations

would be dicussed in terms of how they apply to evaluation scoring. Directions would be given for scoring difficult material. For example, readbacks of the Statement-of-Work on substantive material might receive a uniform score of 25.

Success of the proposed evaluation guide is almost guaranteed. That is, it is well known, Reference 1, that training (which the guide would provide) increases both intrarater and interrater scoring reliability. The guide, resting on foundations of empirical procurement research, should greatly improve the government's source selection process, and attest to the practical value of procurement research.

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THE EVALUATION PROCESS, Survey Items No. 14 and 37

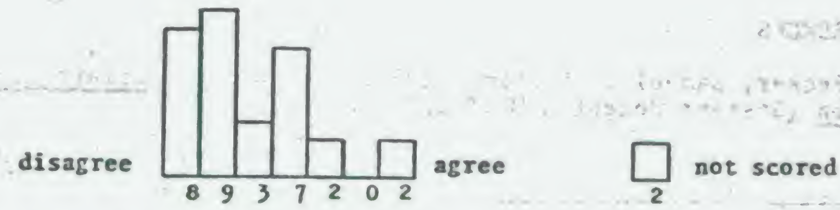
OBJECTIVE: *Examine evaluator attitudes toward the evaluation process.*

QUESTIONNAIRE ITEM NO. 14:

Proposal evaluations are a bore.

disagree _:_:_:_:_:_:_ agree or _ unable to score

RESULTS:



QUESTIONNAIRE ITEM NO. 37:

Proposal evaluations are hard work, but are worthwhile for the government.

disagree _:_:_:_:_:_:_ agree or _ unable to score

RESULTS:

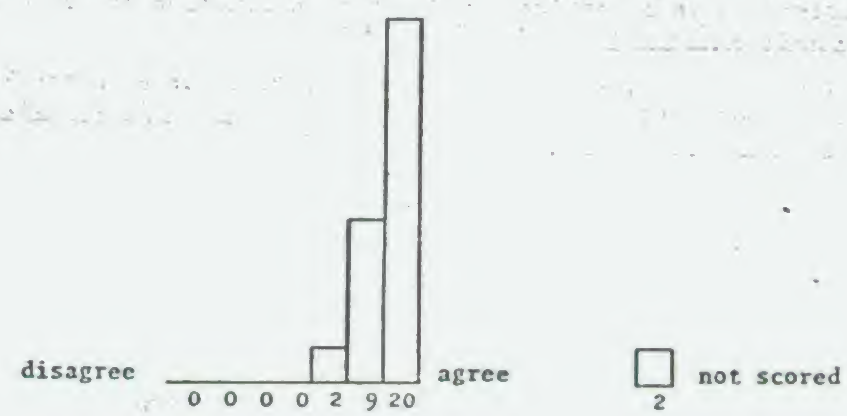


FIGURE 1. Results From the Evaluator Preference Survey Showing Favorable Attitudes Toward the Proposal Evaluation Process

THE EVALUATION PROCESS, Survey Items No. 22 and 43

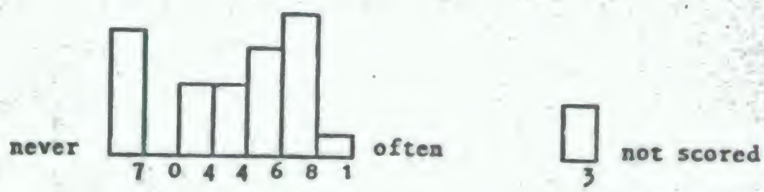
OBJECTIVE: *Examine evaluator attitudes toward the mechanics of the evaluation process.*

QUESTIONNAIRE ITEM NO. 22:

Have evaluation criteria been so poor that you made your own definition or interpretation of the criteria?

never __:__:__:__:__:__:__ often or __ unable to score

RESULTS:



QUESTIONNAIRE ITEM NO. 43:

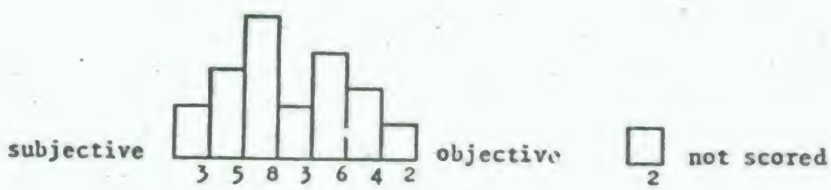
What is your opinion of the evaluation criteria and rating scales used in proposal evaluations?

subjective __:__:__:__:__:__:__ objective or __ unable to score

good __:__:__:__:__:__:__ bad or __ unable to score

fair __:__:__:__:__:__:__ unfair or __ unable to score

RESULTS:



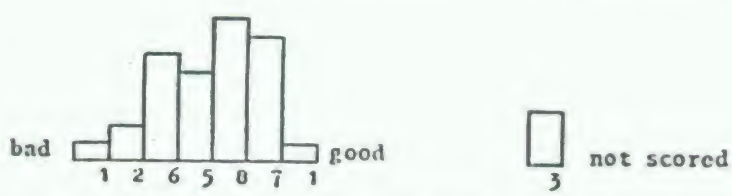


FIGURE 2. Evaluator Preference Survey Data Indicating A Need For Improvement in Proposal Evaluation Mechanics

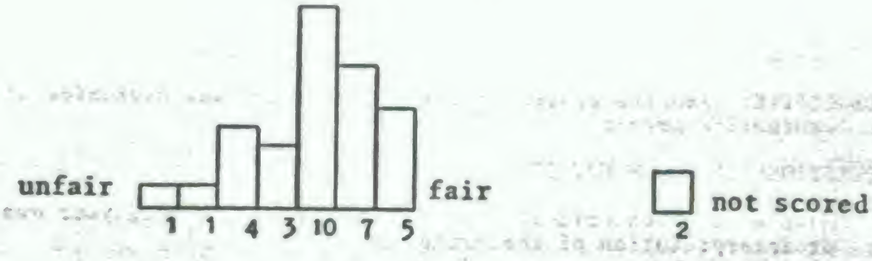


FIGURE 2. (Continued)

100 Excellent (a very comprehensive, complete response to every detail of a respective area).

90 Very Good (a proposal with clear responses to all requirements of a respective area.

80 Good (a proposal with definable detail in excess of the minimum requirements).

70 Average (minimum acceptability, bidder meets minimum requirements).

60 Fair (lack of clarity-implications or vague indication that capability is present in accordance with RFP).

50 Poor (incomplete-omission of minor details-omissions or misunderstandings of requirements in minor areas).

00 Unacceptable (gross omissions or failure to respond to requirements of major areas).

FIGURE 3. The Trucated Adjective-Numeric Rating Scale Used by Subjects in Group 1

+30 Excellent	Will meet minimum requirements with an almost assured probability of sucess; and/or, offers substantial advantage(s) over minimum requirements at no additional or at a reduced cost.
+20 Very Good	High probability that minimum requirements will be met; and/or, offers some advantage(s) over minimum requirements at no additional or at a reduced cost.
+10 Good	Good probability that minimum requirements will be met; and/or, offers small potential advantage(s) over minimum requirements at not additional cost.
00 Average	Should meet minimum requirements.
-10 Fair	Some question that it will meet minimum requirements; and/or, exceeds minimum requirements at some additional cost to the government; and/or proposal is ambiguous or partially unclear.
-20 Poor	High probability that minimum requirements will not be met; and/or, exceeds minimum requirements at an additional cost to the government; and/or. proposal is poorly presented (unclear or large omissions).
-30 Unacceptable	Almost assuredly will not meet minimum requirements; and/or exceeds minimum requirements at a significant additional cost to the government; and/or, fails to address requirement(s).

FIGURE 4. The Experimental Rating Scale Used by the Subjects in Group 4

		Proposal Response			
	A	B	C	D	E
Group 1					
55 Subjects					
Truncated Rating Scale					
Mean	65.2	40.4	87.4	32.7	86.5
St. Dev.	10.0	33.2	12.9	26.4	9.1
Group 2					
37 Subjects					
Linear Rating Scale					
Mean	45.6	23.9	84.9	20.6	77.5
St. Dev.	12.2	26.6	13.3	16.1	17.0

FIGURE 5. Scores for the Same Five Proposal Responses Using a Truncated vs. Linear Adjective-Numeric Rating Scale

	Number of Subjects	Range of Rating Scale	Defined AVERAGE Score	SOW Readback Mean Score
Experienced Government Evaluators From Group 1	15	0 to 100	70	67.3
Group 2	37	0 to 100	50	45.6
Mock Proposal Experiment Experienced Government Evaluators, Conduct of Thermal Tests Contractor A Proposal	29	+3 to -3	00	-0.03
Mock Proposal Experiment Experienced Government Evaluators, Conduct Drop Tests Contractor B Proposal	29	+3 to -3	00	+0.03

FIGURE 6. Scoring of Proposal Material Showing Mean Scores of Direct Readbacks of the Statement-of-Work Consistently Near the Rating Scale Definition of "Average"

EXPANDED AREAS OF CONTRACTING

Expanded Areas of Contracting: A Case Study on the Use of Performance Incentives to Achieve Technological Innovation

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Introduction

The purpose of this paper is to document a procurement experiment jointly sponsored by the Experimental Technology Incentives Program and the Federal Supply Service, wherein performance incentives were employed in an attempt to achieve technological innovation. The paper will first briefly describe the Experimental Technology Incentives Program, in particular the procurement portion, and then document the experiment design and implementation phases. Finally, issues to be resolved in the evaluation phase will be highlighted.

The Experimental Technology Incentives Program

In his March 1972 Science and Technology and 1973 Budget Messages, the President called for a testing of possible partnership arrangements among various Government levels, private firms and universities, and the initiation of a series of experiments to find better ways of stimulating private investment in research and development. This was the birth of the Experimental Technology Incentives Program known as ETIP.

This program, which is under the National Bureau of Standards, is part of a continuing effort, on the part of Federal Government, to find ways in which it can work as a more effective partner with the private sector of our society in the development, application, and transfer of science and technology to strengthen the Nation's economy and improve the quality of life.

The ETIP objective is to conduct an informed inquiry into the relationship between Governmental actions and technological innovation in the private sector. The purpose of the inquiry is to discover and test appropriate Governmental policies and practices which could stimulate desirable innovation in the civilian economy and thus contribute to the solution of national problems. The general method of conducting this inquiry is to work in close cooperation with appropriate Government agencies in the identification, analysis, testing, and evaluation of potential policy related incentives for innovation. The particular policies addressed will be of significant interest to the cooperating agency and will represent a general process which has application in other areas.

This experimental program is designed to gain insight into practical problems by developing unique information from actual experience to be used as the basis for policy recommendations. The Program is divided into three major policy areas: Regulation, Economic Assistance, and Procurement.

Procurement Area

In the Procurement Area, we are testing the hypothesis that the use of procurement incentives in government contracting can encourage suppliers to incorporate new technology in their products being offered both to the government and the c erical sector. It is felt that current procurement methods create barriers to this technological improvement, and the use of incentives can remove these barriers. As an example, the traditional low bid approach used in contracting provides no incentive for a supplier to do better than the minimum performance level specified, thus ensuring that the government will always be in the position of receiving minimum quality level products. The use of life cycle costing can change this situation in that suppliers are put on notice that the government is interested in the best or optimum level of performance rather than the minimum; in the case of procuring appliances, this means that the more energy efficient appliances will fare better in the bid evaluation process since they will have lower overall operating costs. Thus, the low bid barrier has been removed, and suppliers are rewarded for better quality products.

Before undertaking a specific procurement experiment with an agency, several factors must be considered:

- The element of technology must be identified, whether it be energy conservation, higher performance, longer life or whatever. It should be clear at the outset exactly what is to be improved through the experiment.

- The technology element must be ranked and compared in both the Government and commercial markets to identify if the Government leads, lags behind or is even with the commercial market version of a product or product class.

- Agency goals with respect to the desired technology element need to be identified and established as part of the experiment. The ETIP goal of private sector technological innovation as the ultimate goal of the experiment is a long-range one; since the needs of participating agencies often require a more immediate payoff, products tend to be selected for

experiments where the Government version of the product lags behind the commercial market version. The result is two sets of goals being established, short term and long term. In the short term, the agency goal is set at bringing the technology level of their product up to that of the commercial market. Once this has been achieved, the long term ETIP goal of private sector innovation through procurement incentives then becomes appropriate.

- Policy, procedural, traditional and other barriers to agency goal and technology achievement must be identified. Such barriers include risk of buying a product the customer agencies won't use, additional funds to cover the extra cost of a new product submitted in response to an incentive, and lack of properly trained personnel.

- ETIP resources, under the experimental framework can be directed toward developing an experiment to achieve goals and objectives while reducing barriers to innovation in the procurement process.

Once these factors have been considered the design of the procurement experiment begins. Here the ETIP procurement program staff works with the participating agency staff to obtain agency commitment for the duration of the experiment, design the details of the procurement incentive to be tested, if applicable, interact with industry and plan the evaluation of the experiment after each procurement.

Lawnmower Project

Lawnmowers were selected for a procurement experiment because they were an item that the government purchases in large quantities, an item that has an excellent commercial transferability factor, and one that had (at the time) national attention regarding the need for improved safety and lower noise levels. The ETIP staff, therefore, developed in coordination with Federal Supply Service a procurement project which would attempt to encourage suppliers to offer innovative ideas in the areas of safety and noise control. The design of the project called for a definite quantity purchase of 10,000 21" rotary lawnmowers, which in itself was thought to be a sufficient incentive to industry since normal contracting procedures involved indefinite term contracts. The ETIP project plan for this experiment was formally approved in October 1973 and Federal Supply Service issued their bid document to industry on May 29, 1974.

In developing the statement of requirements for the project, FSS worked closely with representatives of the Consumer Product Safety Commission (CPSC) and the Environmental Protection Agency (EPA). The purpose here was to develop goals in the area of safety and noise which would be both realistically obtainable and reflect an improvement over existing technology. In the area of safety, the principal requirements was for a device to be installed on the mower which would automatically cause the blade to stop within 3 seconds after the operator left his station. This requirement, strongly endorsed by CPSC, became known as the "deadman's clutch." In the area of noise, it was felt that based on available commercial mowers ("Lawnmowers: Noise and Cost of Abatement," EPA, June 1974) that a reasonable target goal should be 85dBA (bids above that level would be rejected).

It was decided that the two step formal advertising procedure would best meet the needs of this situation in that the government was calling for technology which was not currently available; therefore, step one of the procurement, the call for technical proposals issued March 19, 1974, with a closing date of May 29, 1974. Eight proposals were received; however, the technical evaluation of the proposals revealed that none of them were able to meet both the safety and noise requirements of the project. The principal factor which caused the inadequate response was the lack of sufficient lead time for suppliers to do any significant developmental work. To overcome this problem, it was agreed by project participants to issue a "letter of intent" to industry which would substantially increase the leadtime between "bid issue date" and the closing date for technical proposals.

Accordingly, FSS issued in September 1975 a letter of intent to industry which announced the future purchase of 10,000 mowers and call for technical proposals to be submitted by January 1976. Additionally, a sliding point scale was incorporated into the method of award which on a scale of zero to 10 rewarded bids which offered noise levels at less than 88 dBA. The procedure called for adding to the suppliers purchase price a maximum of 10 points at the 88 dBA level down to adding zero at the 80 dBA level, with award to be made to the lowest overall combination of purchase price and noise weight factor. The "deadman's clutch" requirement remained constant.

Response to this statement of requirements were few in number and while they appeared to meet the noise level criteria, they did not meet the clutch requirement. After consultations with members of CPSC wherein it was learned that an industry standard

requiring the clutch device was at least a year away, it was decided that the clutch requirements should be dropped and concentrate solely on noise. Additionally, 86 dBA was set as the new maximum level. Suppliers were advised of this fact, and a new submissions date of March 30, 1976, was established. Eight proposals were received under the revised requirements and technical evluation begun. Proposals reviewed were both adequate and encouraging from a noise level viewpoint, and price proposals were requested in June, 1976. Final award was made to AMF Industries in February 1977 for a 21" rotary mower which was rated (by AMF) at 82 dBA. Terms of the contract called for validation of this noise level at the pre-production inspection date of May 23, 1977 and for delivery to start in July, 1977. It is interesting to note that award was not made to the lowest bidder in terms of initial purchase price, which was $92.50 with a sound level of 86. Instead, award was made for the model priced at $102.45, but with a sound level of 82. Thus, the sliding scale of point values was in fact utilized in the contracting process.

What remains to be done, from the ETIP prospective, is to evaluate this procurement from both the agency and commercial impact points of view. What impact has this experiment had on the normal organizational routine at FSS with respect to the interaction between procurement, specification and marketing personnel? One of the more important elements of the experiment in this area was the formation of a team with members from each of the areas present, with clear cut authority to make decisions without resorting to the usual chain of command process. Agency impact evaluation will focus on this process to determine both its effectiveness and probability of being retained.

From the commercial impact viewpoint, ETIP is interested in determining what effect the incentives used in this experiment (definite quantity and sliding scale) actually had on suppliers' decisions whether to participate at all in the procurement and more specifically, what level of developmental effort to put into the bid. Clearly there is an interrelationship of forces between pending industry standards for noise and safety, and the incentives used, and to the extent possible, these forces must be sorted out in answering the question "What caused the supplier to react?" Finally, a decision must be reached on whether to continue this experiment in future procurement cycles to give industry more time to develop innovative products. An essential ingredient in this decision will be feedback from industry regarding the experiment in general and the particular incentives used. Refinements in future cycles would come directly from this feedback.

MANAGEMENT BY OBJECTIVES: CONTRACTOR EMPLOYMENT COMPLIANCE

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INTRODUCTION

On April 18, 1973, a memorandum of significant implication was sent to Secretary of Defense, the Honorable Elliot L. Richardson. That memorandum, signed by the President of the United States, requested the Secretary of Defense (as well as the heads of 20 other Executive Departments and Agencies who received identical memorandums) to focus on the results which the various programs and activities under his direction were aimed at achieving. In particular, the President requested Secretary Richardson to develop a list of major goals and objectives which would be pursued by the Department of Defense (DOD) during the coming year. The President emphasized results, long-term goal setting and short-term objective achievements, and advised that from time to time he would review the progress of DOD toward achieving these objectives.[1] By June 1973, the Office of Management and Budget (OMB), under the direction of the Honorable Roy Ash, had assumed responsibility for the overall direction and coordination of this effort within the Executive Branch. This managerial direction became known as Management by Objectives.

Zero-base budgeting has been called the descendant of MBO. The Government Economy and Spending Reform Act of 1976, requires every government organization to evaluate and review all programs and activities on a basis of output or performance, as well as cost, and to increase analysis.[2] Therefore, Management by Objectives (MBO) is the vehicle to use when deciding where the program should go, how to get there, and in what time period. Zero-base budgeting is the approach to use to determine if the current activities are efficient and effective, and if they should be eliminated or reduced to fund higher priority new programs, or to reduce the current budget.

The purpose of this article is to show the applicability of MBO to the Contractor Employment Compliance function of the Department of Defense, and how its results can be used to support the newer concept, zero-base budgeting. The background of the compliance program will be shown, followed by a description of the MBO technique employed since October, 1976. The conclusion will focus on the way in which MBO data and design can be supportive of the zero-base approach to budgeting.

BACKGROUND

Equal Employment Opportunity is the law. Discrimination is prohibited by the Civil Rights Act of 1964, and Executive Order 11246, as amended. The Order is administered by the Secretary of Labor, through the Director, Office of Federal Contract

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[1] Memorandum for Honorable Elliot L. Richardson, Secretary of Defense, from Richard Nixon, President, April 18, 1973.

[2] Peter A. Pyhrr, "The Zero-Base Approach to Government Budgeting," Public Administration Review, January/February 1977.

Compliance Programs (OFCCP), Department of Labor. Described in Title 41, Code of Federal Regulations, "The Order prohibits discrimination because of race, color, religion sex, or national origin, and requires affirmative action to ensure equality of opportunity in all aspects of employment by all Federal government contractors and subcontractors, and by all contractors performing work under federally-assisted construction contracts."[3]

The Department of Labor, in turn, has assigned responsibility to several Federal Government compliance agencies, by major industry groups, using a Standard Industrial Classification (SIC) code system.[4] A compliance agency is one designated to conduct comprehensive reviews of contractors' employment practices, and to undertake such other responsibilities in connection with the administration of the Order determined by the Department of Labor to be appropriate. The Department of Defense is one of twelve compliance agencies. To accomplish this mission, the Executive Directorate, Contractor Employment Compliance, Defense Logistics Agency, through nine regional offices, conducts an extensive program of compliance reviews.[5] The geographical spread of region responsibilities is illustrated in Table 1. The major industry groups for which the Department of Defense has compliance responsibility are illustrated by SIC codes, in Table 2.

Although the purpose of the Order is to promote and ensure equal opportunity for all persons employed or seeking employment with government contractors, both those contractors who provide supplies and services, and those who perform under federally-assisted construction contracts, this MBO approach considers only the employees for supply and service contractors.

A significant difference in administering the Contractor Employment Compliance program over others in contract administration is the origin of the contract. By using the SIC code method for assigning compliance responsibility to an agency, DOD is concerned with companies who may hold contracts with other Federal government agencies, and not necessarily with DOD buyers. For example, SIC code 027 signifies Printing and Publishing as a major industry group. Therefore, any government agency contracting its printing and publishing work looks to DOD for compliance responsibility. Similarly, there are DOD contracts for which compliance responsibility is held by another agency. An example is wholesale groceries, SIC code 514, a major industry group where the Department of Agriculture has responsibility, regardless of the volume of contracts made by DOD. For uniformity in obtaining data on current contracts, across Agency

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[3]Title 41, Code of Federal Regulations, Chapter 60, Part 1.1, Government Printing Office, July 1975.

[4]Standard Industrial Classification (SIC) code is a numeric coding system, established by the Office of Management and Budget, used to describe major industry groups, and employed by the Department of Labor in assigning responsibility to compliance agencies.

[5]The purpose of the compliance review is to determine if the prime contractor or subcontractor maintains nondiscriminatory hiring and employment practices, and is taking affirmative action to ensure that applicants are employed, and that employees are placed, trained, up-graded, promoted, and otherwise treated during employment without regard to race, color, religion, sex, or national origin. It consists of a comprehensive analysis and evaluation of each aspect of the aforementioned practices, policies, and conditions of employment. Where required, recommendations for appropriate sanctions are made.

procurement lines, information is received on a monthly basis from Dun and Bradstreet. The data provided to each of the nine regions cited above include the name of the contractor, contract number, location, dollar value of the contract, number of employees at each facility, SIC code, and the name of the contracting agency. A contractor universe is a key element in the Contractor Employment Compliance program, and represents the total number of contractors for which DOD has a compliance responsibility. Only those contractors holding current contracts for at least $50,000, and having at least 50 employees, are included in the universe. By the end of FY 76, DOD's contractor universe included 35,600 companies holding contracts for supplies and services.[6]

Each year, the allocated resources permit only 8,000 compliance reviews of contractor facilities, of the 35,600 in the universe. A long-term goal of the Contractor Employment Compliance program is to work toward the net increase in the number of qualified women and minorities employed in contractors' work forces. The minimum rate is a 1% net increase per year. Therefore, the equal opportunity specialist personnel located in the nine regions must schedule and conduct compliance reviews for those contractors located in areas where locally and nationally developed employment statistics show women and minorities exist. These statistics show the availability of employees on a Standard Metropolitan Statistical Area (SMSA), or geographical, basis.[7]

The MBO concept was introduced in the Contractor Employment Compliance program in October 1976, to deal with a problem. The problem is how to establish a method for determining short-term objectives, and measuring program results toward meeting the long-term goal, i.e., the employment of qualified women and minorities at all levels of contractors' work forces, in relation to their availability in geographically stated labor markets.

MANAGEMENT BY OBJECTIVES

At a meeting of the Directors, Contractor Employment Compliance, held during August, 1976, in Alexandria, Virginia, the major program goal was discussed, i.e., to ensure equal opportunity in employment. Inasmuch as there was no method to forecast the rate of progress toward meeting the long-term goal, a research project underway prior to the meeting was introduced. The project was developed at the Headquarters, Defense Logistics Agency in the Executive Directorate, Contractor Employment Compliance. It was entitled Application of Management by Objectives to the Contractor Employment Compliance Program, and it was subsequently implemented in the nine regions, on 1 October 1976. It was selected because it provides for collective reasoning by all personnel, the scheduling of facilities to be reviewed which appear to have the most opportunities for hiring/upgrading employees, and an auditing of the results of the compliance program. The auditing was designed by using the Agency management reporting system, Automated Management Information System (AMIS).[8]

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[6] Contractor Employment Compliance Equal Opportunity Report, Defense Supply Agency, November, 1976, p. 6.

[7] Standard Metropolitan Statistical Area (SMSA) is a numeric coding system, established by the Bureau of Standards, Department of Commerce, for uniform use by Federal government agencies, to designate large metropolitan areas in the US. There are 208 SMSAs.

[8] Automated Management Information System (AMIS) is the management reporting process used by the Contractor Employment Compliance program, with the input of data by the nine regions to a data bank at the Headquarters. The purpose of AMIS is to provide historical and current information. This information is the basis upon which proper management decisions can be made in directing the program.

Data for the period FY 74, 75, and 76 were used to show the percentage trend for net increases, or decreases, in the employment of women and minorities in contractor work forces where region personnel had already made compliance reviews. These data are illustrated for each region on Table 3, by percentage. The short-term objectives to be established each year for a five year period, i.e., FY 77 through FY 81, are whole numbers and percentages, and will be measured against the actual increases shown in forthcoming AMIS reports. MBO is a five year plan, designed in four parts to focus on the annual results of the Contractor Employment Compliance program activities throughout the nine regions. The four parts of the plan follow:

1. Identification of the Responsibility Level. As a decentralized core program, MBO is directed toward a "decision unit" composed of region personnel, with specific geographical responsibility and mission. Therefore, the level of operation for the MBO program exists at the DCASMA.[9] The decision unit consists of assigned personnel, resources, mission and authority. Within each DCASMA there are Standard Metropolitan Statistical Areas (SMSAs) which were mentioned earlier in this article. They are keyed to metropolitan areas, as the name implies, and are used with the data furnished by Dun and Bradstreet in the contractor identification phase, which are designed on a geographical basis.

The DCASMAs are concerned with employment categories. To hire women and minorities in contractors' work forces is not enough to meet the intent of the Executive Order and subsequent regulations. They must be hired and upgraded to be represented at all levels of the work forces, i.e., to higher levels where their qualifications and potential indicate they can be employed. For this reason, the MBO program is based on setting objectives to be reached for each of the nine EEO-1 categories in a given geographical area. An EEO-1 category describes a major employment group expected to be found in a contractor's work force. There are nine EEO-1 categories recognized in industrial personnel systems: Officials and Managers, Professionals, Technicians, Sales Workers, Office/Clerical Personnel, Craftspersons, Operatives, Laborers, and Service Workers.

2. Methodology, and the Use of the "Decision Package." The employment objectives for women and minorities are tied to their availability in a given geographical area, the SMSA, regardless of the type of supply or service the contractor provides. The AMIS data are sorted by EEO-1 category, by SMSA, to establish a method for typing employment levels to availability statistics provided by government sources. Each DCASMA is responsible for gathering the availability statistics.

To compute the objectives, whole number and percentage, a sample chart can be used, Table 4. By using the availability statistics discussed above, there are three remaining factors:

a. Opportunities Index. This number, based on past AMIS data for the period FY 74, 75, 76, is an average of the three year period of the total number of new hires and promotions which occurred in contractor work forces. The opportunities index represents the chances the contractors have had to place or upgrade women and minorities in the reporting period. These data are input into region computer terminals each time a compliance review is completed, and are sorted by EEO-1 category, and by SMSA.

9Defense Contract Administration Services Management Area (DCASMA) is a sub-region unit. Several DCASMAs form a region.

b. Labor Force Percentage. These percentages illustrate the population between the ages of 16 and 60, considered employable, who are women and minorities. They are established by SMSA, not by EEO-1 category, and can be obtained by each DCASMA from the Bureau of the Census, US Department of Commerce. The labor force percentage is the ultimate long range goal of the Contractor Employment Compliance program, that is to say when women and minorities are employed in relation to the labor force percentage they represent.

c. Objectives. The objectives to be set by DCASMA personnel, under the direction of region managers, are the anticipated net changes of employees in each EEO-1 category which are expected to be achieved through the compliance review process. The objectives will be shown by SMSA, and established for each of the five years of the MBO plan.

To compute the objectives the DCASMA personnel use three criteria: availability statistics, opportunities index, and the labor force percentage. The objectives are set to correct those EEO-1 categories where women and minorities are not represented in proportion to their availability in the respective SMSA. According to standards set by the Headquarters managers, no less than a 1% increase per EEO-1 category, per year, will be considered acceptable.

Once the objectives are established by the DCASMA, and the region personnel have reviewed and approved the proposed activity, the resources can be applied. Data resulting from the compliance reviews must be transmitted through the computer terminal to the Headquarters, as required in the regular management reporting system, AMIS.

3. Review. The third of the four part MBO program is a review process conducted at the region and headquarters levels to insure the program is working effectively and efficiently toward the long-range goal. Review of AMIS reports must be made at least semi-annually to measure the impact of the work reported by the DCASMA operational level. Review takes into consideration the objectives, resources allocated, and success of DCASMA personnel while conducting their compliance reviews. The accountability of all DCASMA team members is significant because the success of the program depends on their seriousness of purpose as they make a commitment in setting objectives, and work toward reaching the objectives.

4. Evaluation. Problems encountered must be resolved. For example, use of statistics according to the MBO formula is described easily on paper. In practice, however, the availability of the actual statistics may vary among SMSAs. In such a case, the DCASMA personnel may establish data from their own community resource files before proceeding with the actual objectives. Headquarters personnel examine the effectiveness of the MBO program. This evaluation process requires an effective communication system within the entire Contractor Employment Compliance program. The communication expedited resolving problems as they are encountered, instead of waiting for formal reporting periods.

AMIS data are furnished by the headquarters to the region each six months. In turn, the region studies the results depicted on the reports and sends the material on to the DCASMAs. The data serve as feedback to everyone, and serve as a basis to identify areas which need improvement. The accountability factor embodied in the personnel performance, as team members work individually and collectively to reach short-term objectives, is the most significant part of the MBO program.

The MBO five year plan focuses on results, and provides a data base upon which decisions can be made. For example, if there is a greater likelihood for a net increase in employment to exist at one SMSA over another, resources can be applied to support

that effort. This data base is related to the zero-base budgeting concept. Its review and evaluation process, with cost/benefit focus, tends to support a zero-base budget preparation. Inasmuch as only 22 % of the total number of contractors can be reviewed, the benefits received from the application of resources in each DCASMA are important on a cost/benefit basis.

CONCLUSION

There are two questions raised in the Management by Objectives program which are the focus of the zero-base budgeting process:

1. Are the current activities efficient and effective?
2. Should current activities be eliminated, or reduced to fund higher priority new programs, or to reduce the current budget?

Zero-base is an approach, not a fixed procedure or a set of forms to be applied uniformly from one organization to the next. The four parts of the MBO program applied to Contractor Employment Compliance correspond to the four basic steps of the zero-base approach:

1. Identify decision units
2. Analyze each decision unit in a decision package
3. Evaluate and rank all decision packages to develop the appropriations request.
4. Prepare the detailed operating budgets, reflecting those decision packages approved in the budget appropriation.

Zero-base budgeting calls for a five year plan for annual review and evaluation of programs, on a cost/benefit basis, including the setting of objectives. Program evaluation, operational decisions, and budget preparations are subsequent sequential steps.

The decision packages, developed by DCASMA personnel, can be analyzed in the zero-base approach in light of six criteria:

1. The purpose and objectives of the Contractor Employment Compliance program.
2. The descriptions of actions taken (what, how).
3. The cost and benefit of the program.
4. The workload and performance measures.
5. Alternative means of accomplishing the objectives.
6. Levels of effort, i.e., what benefits are accrued for each level of funding, at the responsibility levels.

The evaluation and ranking of the decision packages enables managers to direct the program, analyze the program at all stages, and apply resources to accomplish the short-term objectives. The MBO data are designed to allow managers to determine if the current activities cited in question one, above, are efficient and effective. These data support managerial decision for continuing, eliminating or reducing the program activities of DCASMAs, in response to question two, above.

Zero-base means the evaluation of all program activity. The evaluation can lead to a complete rethinking and redirecting of the program. Both Management by Objectives and Zero-base Budgeting require a great deal of effective administration, communication and training of all personnel involved in the analysis. These concepts are management and budgetary improvement efforts which may require several years to reach full utilization and effectiveness.

It is my conclusion that MBO is being applied usefully to the Contractor Employment Compliance program. It is applicable to other Compliance Agencies of the Federal Government and should considered by the Department of Labor as a uniform requirement. The fact that Management by Objectives supports the newer concept of

Zero-base budgeting is not coincidental. Rather, it follows a logical course of national direction to insure the wise use of public funds by all government managers, in accordance with the law.

Table 1

EXECUTIVE DIRECTORATE, CONTRACTOR EMPLOYMENT COMPLIANCE
(geographic spread of Region responsibilities)

REGION	GEOGRAPHIC AREA
Atlanta	Georgia, North Carolina, South Carolina, Mississippi, Alabama, Tennessee, Florida, Louisiana (East of the Mississippi River)
Boston	Massachusetts, Maine, New Hampshire, Vermont, Rhode Island, Connecticut, New York (except Westchester, Putnam, Orange and Rockland counties, Long Island and New York City)
Chicago	Wisconsin, Indiana, Illinois (area including and north of the following cos: Vermillion, Piatt, DeWitt, Mason, Tazewell, Fulton, McDonough, Henderson and Champaign.)
Cleveland	Ohio, Kentucky, Pennsylvania (including only Crawford, Erie and Mercer counties), Michigan
Dallas	Texas, Louisiana (west of Mississippi River), Arkansas, Oklahoma, New Mexico, and Arizona
Los Angeles	California, Nevada, Montana, Idaho, Utah, Washington, Oregon, Hawaii
New York	New York (all metropolitan), including Westchester, Putnam, Orange and Rockland counties; New Jersey (north of Mercer and Ocean counties)
Philadelphia	Pennsylvania (except Crawford, Erie and Mercer counties); New Jersey (Mercer and Ocean counties and south); Wash DC, Maryland, Virginia, West Virginia
St. Louis	Missouri, Kansas, Iowa, Nebraska, Wyoming, Colorado, Minnesota, North Dakota, South Dakota, and southern Illinois

Assignment of Compliance Responsibility by Standard Industrial Classification (SIC) Code

OFCCP Order No. 1 (Revised), issued by the Department of Labor, assigns compliance responsibility to each of the compliance agencies according to Standard Industrial Classification (SIC) codes. These SIC codes identify the major activity of a company or its individual facilities. Under this system, DOD has been assigned compliance responsibility for the following SIC codes:

<u>Supply and Service Contractors</u>

22 - Textile mill products
23 - Apparel and related products
27 - Printing and publishing industries
31 - Leather and leather products
33 - Primary metal industries
34 - Fabricated metal products
352 - up to and including
359 - Nonelectrical machinery (except engines and turbines - 351)
36 - Motor vehicles and equipment
372 - Aircraft and parts
376 - Guided missiles, space vehicles, and parts
39 - Miscellaneous manufacturing
501 - Motor vehicles, automotive parts, and supplies (wholesale)
504 - Sporting, photographic and hobby goods (wholesale)
506 - Electrical goods (wholesale)
507 - Hardware, plumbing equipment, and supplies (wholesale)
508 - Machinery equipment and supplies (wholesale)
509 - Miscellaneous durable goods
513 - Apparel, piece goods, and notions
525 - Hardware stores (retail)
527 - Mobile home dealers (retail)
551 - up to and including
552 - New and used retail motor vehicle dealers
555 - Boat dealers (retail)
556 - Recreational and utility trailer dealers (retail)
557 - Motorcycle dealers
559 - Automotive dealers, not elsewhere classified
56 - Retail apparel and accessory stores
739 - Miscellaneous business services

Table 2

TOTAL EMPLOYMENT BY PERCENT

REGION		FY 74 # of Rcds Rcvd	FY 74 %	FY 75 # of Rcds Rcvd	FY 75 %	FY 76 # of Rcds Rcvd	FY 76 %	FY 77 # of Rcds Rcvd	FY 77 %	FY 78 # of Rcds Rcvd	FY 78 %	FY 79 # of Rcds Rcvd	FY 79 %
ATLANTA	Minorities	754	20.4	1062	21.6	1099	21.4						
	Women		39.8		39.1		39.3						
BOSTON	Minorities	466	07.7	630	07.6	543	06.9						
	Women		27.4		26.1		24.8						
CHICAGO	Minorities	465	14.5	504	17.0	541	14.6						
	Women		23.4		26.1		22.9						
CLEVELAND	Minorities	571	15.0	702	15.0	844	13.7						
	Women		17.1		16.9		19.4						
DALLAS	Minorities	674	26.1	738	27.2	723	23.8						
	Women		28.9		32.5		31.8						
LOS ANGELES	Minorities	491	17.1	591	16.8	763	16.2						
	Women		25.0		22.8		22.7						
NEW YORK	Minorities	343	17.4	649	19.6	626	19.9						
	Women		32.0		28.6		29.8						
PHILADELPHIA	Minorities	278	09.3	349	10.2	414	09.6						
	Women		16.9		24.0		21.0						
ST. LOUIS	Minorities	331	08.9	485	09.1	509	09.2						
	Women		23.0		24.8		22.8						

Table 3

REGION ABC

SMSA-160

CATEGORY	TOTAL	WOMEN	BLACKS	SSA	ORIENTALS	AMERICAN INDIANS
OFFICIALS/MANAGERS	50,000	10,000 (20%)	2,000 (4%)	500 (1%)	10 (.02%)	0 (0%)
Requisite Skills		27%	8%	8%	8%	---
Opp. Index	4,000					
Goals (Net Change)		500 (21%)	85 (4.2%)	100 (1.2%)	2 (.024)	---
Labor Force %		40%	10%	4%	1%	---
PROFESSIONALS						
Requisite Skills						
Opp. Index						
Goals (Net Change)						
Labor Force %						
TECHNICIANS						
Requisite Skills						
Opp. Index						
Goals (Net Change)						
Labor Force %						

Table 4

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GRANTS FOR THE SUPPORT OF SCIENTIFIC RESEARCH

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1. The Department of Defense (DoD) is responsible for assuring that the scientific research necessary to accomplish its mission is given adequate support and that it is the policy of the DoD to conduct a broad and continuing basic research program to provide fundamental knowledge, with emphasis on that related to the needs of the DoD.

2. Until 1958, contracts were the only means by which the DoD could arrange for research services or support at either educational institutions and other nonprofit organizations or commercial concerns. Congress had recognized the need for a simple economical and effective instrument, unencumbered by many contract provisions, which would allow certain freedom and creativity to the scientific community. In that year, a law was enacted which, for the first time, gave the DoD authority to expend funds through grants for support of scientific research.

3. Section 1 of that Statute, P.L. 85-934 provides:

> "That the head of each agency of the Federal Government, authorized to enter into contracts for basic scientific research at nonprofit institutions of higher education, or at nonprofit organizations whose primary purpose is the conduct of scientific research, is hereby authorized, where it is deemed to be in furtherance of the objectives of the agency, to make grants to such institutions or organizations for the support of such basic scientific research."

4. Section 2 provides:

> "discretionary authority.... to vest in such institution or organization.... title to equipment purchased with such grant or contract funds"

5. While the authority provided by P.L. 85-934 is quite broad and general, a series of implementing directives have been issued by the Department of Defense imposing certain limitations and restrictions on the use of grants by the military departments.

The directives provide coverage for:

a. Use of Grants - A grant will be limited to the support of those research (authorized by P.L. 85-934) projects which meet relevant research requirements of the Department of Defense.

b. Awarding a Grant - Prior to award, Grantee must have complied with the Civil Rights Act of 1964, through Letters of Assurance, and certain environmental considerations.

c. Qualification of Grantee - Grantee must be a qualified educational institution or nonprofit organization whose primary purpose is the conduct of research.

d. Title to Equipment - Title to equipment purchased with research funds shall be vested in the grantee organization as follows:
(This is essentially the same procedure as for contracts under ASPR)

(1) For each item of equipment having an acquisition cost of less than $1,000 title shall be vested automatically in the grantee organization upon acquisition.

(2) For items of equipment having an acquisition cost of $1,000 or more title shall be vested in the following manner:

Title to Government property for performance of work under the grant and purchased with research funds will normally vest in the grantee upon acquisition.

If there is a genuine basis for expecting that a Government need will exist at the end of the research period, title will vest in the grantee upon acquisition subject to a right of the Government to direct transfer of the title to the Government or to a third party authorized to receive it within 4 months after completion of the grant.

If the contracting officer determines that vesting of title in the grantee would not be in furtherance of the DoD's research programs, title will vest in the Government.

e. Contents of Grant - Grant agreements shall be brief and contain only those provisions which are required by Statute or are necessary for the protection of the fundamental interests of the DoD. Provision shall be made for:

(1) Maintenance of adequate records to document the actual amount of any participation and to determine whether grant funds are properly expended.

(2) Provisions for appropriate patent and data rights.

(3) Provisions for revocation of the grant.

(4) Provisions for the grantee organization to:

(a) Obtain approval from the grantor agency before changing the principal investigator.

(b) Keep the grantor agency informed of any desired major deviation from the planned work and progress under the grant.

(c) Furnish results of all research to the grantor agency.

f. Cost Sharing - Cost sharing (participation) in the support of research shall be encouraged, except when the organization has little or no non-Federal sources of funds from which to make a cost contribution.

GRANT CONTROLS

1. While many of the checks and balances inherent in cost reimbursement contracts either do not appear, or appear in a more relaxed form, in our grants, adequate controls are provided to insure that grants properly protect the Government's interests, and that neither the quality nor quantity of research results obtained have been adversely effected by their use. To insure that available funds are employed in such a manner as will be most likely to provide the Government with the maximum return for its investment, the need for certain safeguards and controls is obvious. Some of the areas in which such need has been recognized, and the extent to which our grant procedures satisfy this need, are as follows:

a. Basic research proposals are selected for support without regard to the type of instrument which will be used. A small percent of the proposals received are ultimately selected. This selection is based largely on the relative scientific merit of the technical proposal and the standing of the prospective investigator, and the institution with which he is affiliated, in the scientific community. Only after a proposal has been found to merit support, based purely on scientific and technical considerations in competition with all others, is consideration given to the amount of funds requested and the form of research agreement to be employed. In such a highly competitive climate, we are reasonably assured of high-quality research results regardless of the method by which support is provided.

b. The same criteria is used for contracts and grants in determining whether proposed costs are fair and reasonable, and both costs are subjected to the same degree of analysis. Negotiations are conducted in the same manner, and determinations as to reasonableness are equally substantiated, regardless of the type of research agreement to be used.

c. A number of essential controls are provided by the grant document, itself. Among these are the following:

(1) The grantee's research proposal is incorporated by reference. The grantee agrees to adhere thereto in the conduct of the research. While the nature of basic research is such that the widest practicable latitude for its conduct should be provided, so long as there is not a departure from the objectives forming the basis for its selection for support. We make no attempt to direct the manner in which the research is conducted, but do provide safeguards against undesirable departures through a system of technical monitorship and retention of a unilateral right to revoke the grant at any time.

(2) Grant brochures for basic research are incorporated by reference. They generally establish the framework within which the research project will be conducted and the grant will be administered. It makes appropriate disposition of such matters as relate to patent rights, rights in technical data, revocation, security, unexpended funds, title to equipment, equal employment opportunity, etc.

(3) Reports of research results, identical to those we require under our research contracts, are provided for in our grants.

(4) Reports of actual expenditures by major categories of cost are required to be submitted annually and at the end of the grant period. Comparisons between these reports and the original estimates enable us to determine the extent to which cost objectives have been met. Selective audits are made to verify accuracy of reporting, and demands are made for the return of improper expenditures. Demonstrated fiscal responsibility weighs heavily in determining whether to continue support of on-going projects or new projects at a given institution.

(5) In their negotiation and administration, we treat grants as a simple form of fixed-price agreement providing for advance payments. Once executed, the grant amount is a fixed-ceiling amount. The grantee absorbs 100% of all costs incurred in the conduct of the research project in excess of the grant amount and returns any remaining funds at the end of the grant period.

CRITERIA FOR SELECTION OF GRANT OR CONTRACT IN AIR FORCE

1. Policy - It is the policy of the Air Force to use grants for the support of scientific research programs whenever the contracting officer considers such use appropriate. A grant will be used except when any of the following factors are present - in such cases a contract will be used:

a. When any portion of the actual research services will be subcontracted (consultants are not considered subcontractors).

b. When a proposal is obtained through the formal solicitation process.

c. When the type of work requires close technical monitoring during the course of performance.

d. When greater fiscal control through vouchering and audit is desired by the Government.

e. When the research requires security classification.

f. When more than 25% of the funds requested is for the purchase of equipment.

A COMPARISON OF AFOSR GRANTS VS CONTRACTS

AREA	CONTRACTS	GRANTS
COSTING	Use of Section XV of ASPR - Cost Principles and Procedures	Use of Section XV of ASPR-Cost Principles and Procedures
INSTRUMENT	Voluminous schedule, special and general terms and conditions (25-30 pages) which are required by ASPR. Subject to frequent changes.	Single page, incorporating standard terms of printed brochure and grantees' proposal by reference.
WORK STATEMENT	Required under every contract describing work to be performed.	None specifically required. Proposal is incorporated into grant by reference, and serves as the work statement.
PAYMENT	Vouchers required to be prepared (usually monthly), and payment made after review, approval and processing required by audit.	Payments are made in advance, on periodic basis.
FILE DOCUMENTATION	Must include considerable support documentation such as certifications and representations. Determinations and Findings under ASPR.	Very limited information is required.
ADMINISTRATION	Considerable communication with contractor is required concerning matters where the C.O.'s authorization must be had before contractor may act.	Little communication necessary for grant administration.
PROPERTY	Must secure approval of facilities acquisition including a Facilities Acquired or Fabricated clause in the contract listing the items authorized.	No facilities acquisition approval required. Listing of items in grant required.

AREA	CONTRACTS	GRANTS
TERMINATION	Termination C.O. must be appointed, termination claim submitted, and lengthy formal settlement agreement negotiated.	Unilateral, one page revocation.
CLOSING OUT	Great delays experienced because final audit is required on each contract and because of the very long period before many overhead rates are established so the final voucher can be submitted.	Closing out may simply be completed as soon as final reports (technical, fiscal, patent) are submitted.

CURRENT GRANT LEGISLATION

1. Legislation is currently being proposed which has as its purpose "to distinguish Federal grant and cooperative agreement relationships from Federal procurement relationships," so as to "standardize usage and clarify the meaning of legal instruments which reflect such relationships". This action is being pursued through Senate Bill S. 431 sponsored by Senator Chiles and companion House Bill H.R. 1503 sponsored by Mr. Horton, 95th Congress, 1st Session. Legislation on similar bills has been proposed as far back as 1973 but were never enacted. The basis for such legislation stems from a study by the Commission On Government Procurement reported in 1972 under which a recommendation, referred to as F-1, was proposed. The proposed bills essentially are implementing this recommendation. Basically the proposed legislation provides that:

a. Transactions in a procurement mode (direct benefit to the Government) will be made by contract.

b. Transactions in an assistance mode (not for the direct benefit by the Government) will be made by grant or cooperative agreement.

2. DoD had difficulty in accepting the bill as written since DoD sponsored research programs are intended to obtain scientific results primarily for Government use to further its mission. The use of a grant in the assistance mode, i.e., for the direct benefit of the grantee as defined in the bill would not be appropriate for DoD use.

3. As was indicated before, Congress in 1958 recognized the need to minimize the administrative burdens on the military departments, universities and non-profit organizations engaged in basic scientific research and enacted P.L. 85-934 particularly to authorize the use of grants instead of contracts as simple instruments to formalize agreements in basic research.

4. It should be noted that this concept for supporting basic research under P.L. 85-934 as envisioned by Congress has not changed. In fact the validity of the concept has been greatly reinforced by DoD success in acquiring research more economically.

5. The proposed legislation would repeal P.L. 85-934 and would limit the use of grants to Federal assistance programs. Passage of the bill would deprive agencies of this established and successful grant authority and would require the acquisition of research by less economical means.

THE RELATIONSHIPS BETWEEN SOCIOECONOMIC PROGRAMS AND THE DEPARTMENT OF THE AIR FORCE BUDGET: SECTION 8(a) OF THE SMALL BUSINESS ACT--THE ECONOMIC DEVELOPMENT AND PUBLIC FINANCE ASPECTS OF A PUBLIC POLICY PROGRAM

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INTRODUCTION

Shrinking real budgets over the last decade have imposed a resource constraint problem on the Armed Services without precedent in the post-World War II era, given the assessment of the military threat. During this same period debate has raged over the cost of providing an "adequate" defense posture and the services have been required to implement programs which did not contribute directly to "national defense". The procurement process is one of the areas upon which several socioeconomic programs have been superimposed for implementation. The socioeconomic programs alluded to here include, but are not limited to, the Small Business Set-Aside Program; the Davis-Bacon Act; the Service Contract Act; the Walsh-Healy Act; and the Section 8(a) Program.

The Section 8(a) Program has received much emotional debate over the last several years. The program has been questioned on judicial and political grounds and there has been considerable controversy over the efficacy of the concept of minority capitalism into which it was made to adapt. The program is administered by the Small Business Administration (SBA) under Section 8(a) of the Small Business Action of 1953, as ammeded. Under this provision of the act, SBA is permitted to contract with other government agencies for the provision of goods and services and then subcontract with private firms to do the actual work "whenever it deems such action is necessary".[1] This provision of law as singled out to become the foundation of a major portion of the Federal Government's Minority Enterprise Program in 1969. It was the vehicle to be used in helping minority owned firms to become more viable business entities by allowing them to secure government contracts noncompetitively.

"The basic aim of Section 8(a) is to establish [minority] business concerns that will become independent and self-sustaining in a normal competitive environment."[2] Thus, the

Section 8(a) Program is a domestic economic development program which has nonwhite minority group socioeconomic mobility as its principal goal. This program, as all other socioeconomic programs, should be judged on the basis of whether its goals are worthy of pursuit; whether it is accomplishing its goals; and whether the benefits of goal accomplishment outweigh the costs. Within the context of the overall national interest, the political decision process determines which public policy goals are to be pursued as well as the manner of pursuit. The sheer magnitude of defense procurement expentitures make them stand out as a vehicle through which other national goals can be pursued. Indeed, they have been used for such purposes since "the eight-hour work day was first extended to workers employed by contractors and subcontractors engaged in Federal projects in 1892."[3]

GOALS AND SCOPE OF THE RESEARCH

This research attempted to answer two questions: 1) To what extent do socioeconomic programs impinge upon the procurement process? and, 2) What are the relationships between underdevelopment and public policy activities designed to combat it in underdeveloped courtries on the one hand and in underdeveloped sectors of economically advanced countries on the other? The research addressed itself to the applicability of general economic development theory to the economic development problems which confront underdeveloped sectors of advanced economies through consideration of one public policy program and one underdeveloped sector -- The Section 8(a) Program and the nonwhite minority group sector[4] of the United States economy. A basic purpose of the research was the development of a framework and rationale for the evaluation of socioeconomic programs.

The research attempted to answer the questions posed above through the accomplishment of three goals. The first of these was the development of a theoretical framework within which the Section 8(a) Program and similar socioeconomic programs could be evaluated. The second goal was the development of a model which could be used to evaluate the effectiveness of socioeconomic programs. A third goal was the development of a method of evaluating the costs of socioeconomic programs to agenices which implement them.

METHODOLOGY

This study was based in the analytical framework of the theory of economic development. This approach to the economic problems of American nonwhite minority group members is neither novel nor new. Gustav Ranis had observed the simlarities between underdeveloped countries and American minority groups in an article entitled "Economic Dualism at Home and Abroad" in the Fall 1969 issue of Public Policy. The quantitative model used in the analysis was developed for this research. It translated the available data on Air Force Section 8(a) contracts into variables theoretically important to minority group economic development. The cost of implementation analysis was based upon answers to a survey questionnaire which was sent to Air Force procurement offices.

The method used in the first portion of this research was primarily descriptive. It investigated the applicability of traditional economic development theory to underdeveloped sectors of advanced economic by analyzing the scope, magnitude, and principal components of the minority group economic underdevelopment problem. The role of public policy in economic development; the ecomonic development potential of minority capitalism; and the genesis of the Section 8(a) Program were then treated. The second portion of the research provided a quantitative assessment of the effectiveness and cost of Air Force participation in the Section 8(a) Program. The third portion of the research provided a summary and conclusions.

MINORITY GROUP UNDERDEVELOPMENT

The minority group economic underdevelopment problem which gives rise to the need for governmental socieconomic policy intervention bears more detailed consideration. One of the cornerstones of the descriptive analysis was the vicious circles of underdevelopment argument developed by Gunnar Myrdal in the 1950s.[5] According to this argument, underdevelopment begets itself through persistent interaction of the relevant variables all reinforcing each other to impede economic development. In this manner, the amplitude of waves which migh otherwise result in development take-off are dampened. The argument is fully applicable to underdeveloped sectors. For example, members of American minority groups have, in general, had less education attainment

than average; which reinforced job bias in the form of decreased upward employment mobility and increased unemployment and underemployment; which decreased the ability to purchase suitable housing; which led to inferior educational attainment; and so on. Indeed it was this circle of underdevelopment that the civil rights laws of the 1960s sought to undermine.

The minority group sector of the United States economy is also similar to underdeveloped countries in terms of the characteristics of underdevelopment which are prevalent in it. The major components of the minority group underdevelopment problem in relation to averages for the society as a whole are: low income measured either in per capita or median family terms; a lack of resource ownership, including human and physical capital; and persistently high unemployment and underemployment. These underdevelopment characteristics have been reinforced by interpersonal and institutional discrimination which relegated minority group members to lower job and socioeconomic classifications based upon racial identity.

Income

Income is the most quantifiable aspect of welfare. Albeit obvious that American minority group members as a whole are better off than the majority of the populations of most underdeveloped countries, they are much worse off than their white fellow citizens as a whole. In terms of the indicators of underdevelopment discussed above, the following examples point out the disparities between this sector and the larger society. The percentage of minority group members below the poverty line was approximately two and one-half times the percentage of the entire society below the poverty line for each year between 1959 and 1971.[6] Median family income for minority group members as a percentage of white median family income has steadily increased from 51 percent in 1947 to 63 percent in 1971, however the dollar difference in median family income has also steadily increased.[7]

Resource Ownership

Many economists believe that capital occupies a central position in the theory of economic development. It performs double duty in that it increases current aggregate demand through its role as investment, while simultaneously insuring that the capability of the economy to produce in future

periods is increased. Human capital as well as physical capital formation is important to economic development. Examples of human capital formation include expenditures for education, skills improvement, health, and internal migration to allow the population to take advantage of better job opportunities. The minority group sector possesses less human capital than the average for the society.

It is possible to arrive at more precise estimates of the lag in ownership of quantifiable physical capital. Minority group members constituted 17 percent of the United States population in 1969. In that same year they owned 4.3 percent of all business enterprises in the country and received only .7 percent of all business receipts.[8] This lack of profitable business ownership affects both the prospects for upward socioeconomic mobility and the current income position of minority group members. The Section 8(a) Program was an explicit attempt to improve the economic prospects for this group by improving its business prospects.

Unemployment and Underemployment

Historically unemployment rates for minority group members have been about twice as great as that for white members of the society. This has been true regardless of the age or sex of the group that is compared or the general economic climate at the time of the comparison. Underemployment is a far more pervasive and insidious problem for minority economic development prospects. It is likely that underemployment is much more prevalent among minority group members than the larger society owing to the job opportunity structure.

RATIONALE FOR SECTION 8(a) PROGRAM IMPLEMENTATION

The Section 8(a) Program was born out of the civil rights progress and civil strife of the last two decades. The guarantee of the full power of citizenship without the encumberances of discrimination was implicit in the laws passed and executive orders issued on behalf of minority group members. This program was but one part of the Federal Government's Minority Business Enterprise effort. It sought

to complement congressional action to prohibit discrimination in voting, housing, employment, and educational opportunity by seeking to remedy a manifestation of unequal access to one type of remuneration--business ownership. The National Commission on Civil Disorders concluded that the riots which rocked the ghetto areas of major cities in the middle 1960s resulted from a sense of alienation from the social and economic systems of the country on the part of minority group members. The Commission's report stated that,

> The expectations aroused by the great judicial and legistative victories of the civil rights movements have led to frustration, hostility, and cynicism in the face of the persistent gap between promise and fulfillment.[9]

Defusing the riot environment was a major goal of President Johnson's Test Cities Program in which the idea for the Section 8(a) Program made its debut. Thus, the Section 8(a) Program was reactive in its attempt to provide for equality of opportunity and simultaneously stabilize a threat to the fabric of the society. The program took on its current form through a series of executive orders and memoranda with congressional knowledge and encouragement.

Federal procurement is big business. Federal contract awards amounted to more than $52 billion in fiscal year 1974. Congress has declared its intent to monitor and influence the distribution of benefits from these expenditures since it passed the Armed Services Procurement Act in 1947.

ECONOMIC DEVELOPMENT EFFECTIVENESS AND COST OF THE SECTION 8(a) PROGRAM

The quantitative portion of this study was comprised of an analysis of the economic development effectiveness and cost of Air Force participation in the Section 8(a) Program.

Development Effectiveness of Air Force Participation

This research used a multiple linear regression analysis to investigate the economic development effectiveness of Air Force participation in the Section 8(a) Program. The

analysis was conducted on 12 variables associated with 935 Air Force Section 8(a) contracts awarded to 365 firms between 1968 and 1976. Two separate regression analyses were conducted on the effectiveness of Air Force participation in the program. The regression analyses postulated a linear relationship between the variables and was expressed as:

Development
Effectiveness $\simeq$ $S = f(N, Y, T, D, G, M, V, P, C, R)$ (Equation 1)

Where:

S = Total dollar amount of Air Force Section 8(a) contracts awarded this firm since FY 1968

N = Number of Air Force Section 8(a) contracts awarded the firm

Y = Fiscal year in which the first Section 8(a) contract was awarded the firm

T = Type of contracting done by the firm:
1 = Manufacturing
2 = Service
3 = Construction

D = Percentage of the population which was nonwhite in the city of contract award

G = Minority group of the firm:
1 = Black
2 = Puerto Rican
3 = American Indian
4 = Spanish American
5 = Asian
6 = Eskimos and Aluets
7 = Undetermined (none in the sample analyzed)
8 = Others - including whites

M = Total number of Section 8(a) contracts awarded this firm by all other federal agencies

V = Total dollar value of Section 8(a) contracts awarded this firm by all other federal agencies

P = Population size of the city of award in 1970

C = Business class of the firm:
1 = Manufacturing
2 = Construction
3 = Service

R = Small Business Administration region in which the firm was located (regions are numbered 1 through 10)

An alternative formulation of the model specifies the dependent variable as the dollar amount of each Air Force Section 8(a) contract written and was expressed as:

Development Effectiveness $\simeq$ A = f(S,N,Y,T,D,G,M,V,P,C,R) (Equation 2)

Where:

A = Dollar amount of this contract

Y = Year of contract award

All other variables are as specified in equation 1.

The linear form of the equations was expressed as follows:

$$S = \text{Alphas} + b_1N + b_2Y + b_3T + b_4D + b_5G + b_6M + b_7V + b_8P + b_9C + b_{10}R + u, \text{ and,} \quad \text{(Equation 1a)}$$

$$A = \text{Alpha} + b_1S + b_2N + b_3Y + b_4T + b_5D + b_6G + b_7M + b_8V + b_9P + b_{10}C + b_{11}R + u \quad \text{(Equation 2a)}$$

Where:

Alpha is the intercept term, b_1 through b_{11} are the beta coefficients, and u is a randomly distributed error term with mean zero.

The data for the research was extracted from the Small Business Administration's Status Report of 8(a) Contracts and the Department of Commerce, Bureau of the Census' 1973 Country and City Data Book and 1970 Census of Population. General Social and Economic Characteristics PC(1) series. Thirty two Air Force contracts awarded to 19 firms during the fiscal year 1968-1976 time period were excluded from the analysis because all relevant data on them could not be obtained.

The regression results indicated that the Section 8(a) Program was a positive economic development tool. The F-test ratio was statistically significant at the 99 percent confidence level for both specifications of the independent variable. The F-test ratio was 5.10 for equation 1 and 15.51 for equation 2. The critical numbers for samples of these sizes and numbers of degrees of freedom were 2.70 for equation 1 and 2.66 for equation 2. Table 1 summarizes the statistical results for individual independent variables.

Cost of Air Force Participation

The research attempted to contruct a rough cost estimate for Air Force participation in the Section 8(a) Program. The vehicle for the cost estimate was a survey questionnaire which was sent to 81 active Air Force installation procurement offices. The estimate was based on answers contained in the 74 questionnaires which were returned (two questionnaires were returned later which did not alter the results). The formula used for computing dollar costs extracted the modal grade of the procurement offices' Small Business Specialist and multiplied the midpoint of the salary for that grade by the midpoint of the modal class of time spent on the program. It added an increment of salary for assistants to the Small Business Specialists, computed in a like manner. A summary of the computation for the cost of the program to 81 active Air Force installation is as follows:

Salary paid to Small Business Specialists	$21,970
Percent of time spent on Section 8(a) procurement	2.5
Salary paid to other procurement personnel	$17,523
Percent of time spent on Section 8(a) procurement	2.5

Estimated dollar cost of time spent per installation per year = ($21,979 x .025) + ($17,523 x .025) = $549.25 + $438.08 = $987.33. The agregate dollar cost to the Air Force for participation is then: $987.33 x 81 = $79,973.73.

TABLE 1

STATISTICAL SIGNIFICANCE
OF INDEPENDENT VARIABLES

Variable	Equation 1	Sign (Beta)	Equation 2	Sign (Beta)
N	YES	+	YES	-
Y	YES	-	YES	+
D	NO	-	NO	-
M	NO	-	YES	-
V	YES	+	YES	+
P	NO	+	NO	-
T_1	YES	+	NO	+
T_2	YES	+	YES	+
T_3	*		*	
G_1	*		*	
G_2	NO	-	NO	-
G_3	NO	+	YES	+
G_4	YES	+	NO	+
G_5	NO	+	YES	-
G_6	NO	+	NO	-
G_7	**		**	
G_8	NO	+	NO	+
C_1	NO	+	NO	+
C_2	NO	-	NO	-
C_3	*		*	
R_1	*		*	
R_2	NO	+	NO	-
R_3	NO	-	NO	-
R_4	NO	+	NO	+
R_5	NO	+	NO	-
R_6	NO	+	NO	+
R_7	NO	+	NO	-
R_8	NO	-	NO	-
R_9	NO	+	NO	-
R_{10}	NO	-	NO	-
S			YES	+

* Dummy variable reference category

** No contracts awarded this category

The respondents to the questionaire were asked to estimate the nonmonetary cost of the program to the Air Force through a series of questions about the impact of the program. When they were asked to rate the program on a scale of 1 to 9 in terms of excessive cost to the procurement process compared to normal procurement, the average response was 6.47. When asked whether the program had adverse impacts on the missions of their organizations and the mission of the Air Force, 72 and 74 percent, respectively of the respondents thought it did not. Fifty seven percent of the respondents thought that the program had more favorable than unfavorable impacts.

CONCLUSIONS

Federal public policy activities are deemed to be warranted when the externalities associated with some phenomena can only be captured at the national level. Minority group economic underdevelopment is such a phenomenon. The analysis associated with this research effort suggests that the Section 8(a) Program is a useful tool with which to combat the business underdevelopment aspect of the minority group economic underdevelopment problem. The statistical results indicate that increased emphasis on the program should yield increased development effectiveness. The program should not be expected to do more than provide an equal opportunity for minority group businessmen to succeed or fail on their merits. It appears to be meeting this challenge.

The program was not found to be inordinately expensive to the procurement process either in terms of dollar costs, excessive procurement cost, or adverse mission impacts. It is likely that the same is true in other federal agencies.

More research is needed to facilitate evaluation of the cost and effectiveness of socioeconomic programs in accomplishing their stated goals. Just as budget constraints in the Department of Defense do not permit the dedication of funds to ill-conceived or ill-planned programs, national resource allocation considerations dictate that benefits are reaped commensurate with money expended in pursuit of national goals.

FCOTNOTES

[1] See U. S., Congress, House, Select Committee on Small Business, Text of Public Law 85-536 (Small Business Act), 91st Cong., 2nd Sess. (Washington: Government Printing Office, 1970).

[2] U. S., Department of Commerce, Office of Minority Business Enterprise, Sepcial Catalog of Federal Programs Assisting Minority Enterprise (Washington: Government Printing Office, 1971), P. 33.

[3] U. S., Commission on Government Procurement, Report (Washington: Government Printing Office, 1972) Vol. I, P. 112.

[4] For purposes of this study, a sector is defined to be any group with common, identifiable characteristics such as the ethnology, sex, or geographical location of its members.

[5] cf Gunnar Myrdal, Economic Theory and Underdeveloped Regions (new York: Harper and Row, Publishers, 1957).

[6] U. S., Executive Office of the President, Office of Management and Budget, Social Indicators, 1973 (Washington: Government Printing Office, 1973), Table 5/17 and 5/19.

[7] U. S., Department of Commerce, Bureau of the Census, Statistical Abstracts of the United States, 1973 (Washington: Government Printing Office, 1973), Table 535.

[8] U. S., Department of Commerce, Bureau of the Census, Minority-Owned Businesses: 1969 (Washington: Government Printing Office, 1971) P.2.

[9] U. S., National Advisory Commission on Civil Disorders Report (Washington: Government Printing Office, 1969), P. 92.

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THE PROCUREMENT AND MANAGEMENT OF A GOVERNMENT OWNED/CONTRACTOR OPERATED (GOCO) ELECTRONIC REPAIR FACILITY

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As a practicing electronic engineer within the Department of Defense, I have often wondered why I ever bothered to earn a degree in engineering. All of those long nights studying advanced calculus, transmission lines, and AC machinery was for naught. This fact becomes particularly evident when one graduates into the engineering management field. Now your need for engineering skills declines expotentially and your need for business and accounting knowledge increases geometrically. A new type of "street wariness" is now required. The old skills that have for so many years carried you up the ladder are useless. No longer does two plus two always equal four. The fact that you are or were a good engineer becomes absolutely meaningless. Suddenly, after so many years of warmth and security the unsuspecting engineer is thrown out into a dark cold world. Scared and very disoriented, he is ready prey for battle scarred contracting officers, nervous accountants and hawkeyed marketeers.

A few months pass and the fledgling engineer manager has had time to test his wings. He has discovered that in management and contracting everyone does not tell the whole truth (on the other hand, engineers never lie to one another). He has discovered that reports, management information systems, and organizational charts are the least of his worries. He is now the leader of a group of ten or so

engineers and technicians who all want to go their separate ways. Alternately, the new manager must be chaplain, father, sheriff, and sea lawyer. Thinking that all that can happen to him has happened, he is suddenly confronted by the Commanding Officer of his activity and asked to supervise work on a new contract effort.

Perhaps a little background information is necessary to discover how our naive engineer became entangled in this trap.

On 1 May 1975 the NAVELEXSYSENGCEN Portsmouth took occupancy of a rented 28,000 square foot former appliance center located at 7454 North Military Highway, Norfolk, Virginia. NAVELEX Headquarters, Washington had given the go ahead to establish an east coast electronic repair facility in the Norfolk area. The original plan called for a build up over a three year period to 150 civil service electronics workers. The facility was named EMC, the Electronic Maintenance Center.

Five months to the day after the building was rented, the doors were open for actual production work. However, as NAVELEX Portsmouth started to implement the original manning plan it was discovered that temporary constraints precluded ceiling points being made available for the new Electronics Maintenance Center. In order to operate, the facility was staffed with temporary Civil Service employees. It was hoped that these temporary positions could be covered to ceiling points upon their expiration date of 1 July 1976. To the dismay of NAVELEX Portsmouth, NAVELEXSYSCOM Washington notified the command that ceiling points would not be made available and that other staffing arrangements would have to be made for continued operation.

In April 1976, our engineering friend was asked to assume temporary management responsibility for the EMC facility. This was necessitated by the retirement of the supervisor responsible for the EMC operation. This temporary assignment was to be in addition to his present position as Head of the Test Measurement and Diagnostic Equipment and Radiac Division of NAVELEX Portsmouth. Little did he know at this time what lay ahead.

The future of the Electronic Maintenance Center was very much in doubt during the spring and early summer of 1976. The only way to continue operation of the facility after July 1976 would be some type of contracting effort. At this time, the EMC facility employed some fifty temporary and six permanent civil service employees. Due to the short history of the maintenance center, adequate specifications were not available to solicit competition, and time did not allow for submission of technical proposals.

Now what? Time was short. The contracting effort for the EMC operation was a somewhat difficult task even for an experienced person, much less a relatively inexperienced engineer.

As often happens when things appear to be hopeless, an unexpected ray of light shown thru the clouds.

Superior Engineering and Electronics Company of Los Angeles, California learned of the situation and submitted an unsolicited proposal for the operation of the Norfolk facility to NAVELEXSYSCOM Washington. This proposal was forwarded to NAVELEX Portsmouth for consideration. Superior is a one-hundred percent minority owned company certified eligible under the 8(a) program. Their area of specialization includes shipboard systems integration, engineering, overhaul, fabrication, installation, modification, and checkout of electronic and ordnance systems. In November of 1975 they were selected as one of the outstanding small business firms in their region (region nine (9)).

Everyone at NESEC Ports was somewhat skeptical. It was a foregone conclusion that the 8(a) program was a training program. Because there is no competitive bidding and owing to the fact most 8(a) contracts contain what amounts to learning process subsidies, the cost of the contract would necessarily have to be greater. The decision came down to this: was it better to try an 8(a) contractor or close up shop and do no repair work at all. Subsequently, NAVELEXSYSENGCEN Washington, in accordance with DOD policy (ASPR 1-705.5(b)) indicated a desire to award an 8(a) contract to a highly qualified firm for the operation of the Norfolk facility.

The decision was made and work was started on the contract. During the period May to September 1976, many hours were spent in writing requirements and deciding on what functions would be contracted and which would remain the responsibility of the government. In June of that year, a rough solicitation was completed. Working very closely with the Negotiator and Contracting Officer from the Regional Procurement Department of the Naval Supply Center Norfolk, NESEC Portsmouth refined the scope of the proposed contract and closed in on what it considered to be a final solicitation.

The original solicitation called for a combined firm fixed price and time and materials, indefinite delivery type contract. This type contract calls for submission of clearance prior to placement of individual orders. Negotiations with Superior began in July. A reprieve was granted to extend all temporary employees through the end of FY7T (30 Sept 76). Even with this, uncertainty and attrition had reduced the work force at EMC to thirty temporary Civil Service employees.

During negotiations, it was determined that a change in contract type was in order. It was decided that a cost plus award fee contract would be to the mutual advantage of the Government and Contractor. On a closer examination, it was discovered that a further breakdown

of services would be required; the management of the facility, and the direct labor effort. On advice from the NSC Norfolk Procurement Department, the management portion would be a firm fixed price for a one year period based on a labor effort of 75 ($\pm$ 25%) direct production personnel. The direct labor effort would be a cost plus award fee because it would be impossible at the time of contract award to know with any degree of certainty the level of work or amount of materials necessary to perform the required overhaul. Both the government and contractor would derive certain benefits from the combination of firm fixed price and cost plus award fee.

By mid July, final negotiations were in progress. A meeting was held with representatives of Superior Engineering, NSC Norfolk and NAVELEX Portsmouth in attendance. A final contract agreement was reached. The NSC Procurement Department wrote the business clearance and forwarded it to Chief of Naval Materials for approval. Time was growing very short. In late August, approval was finally received from NAVMAT. One last hurdle remained, the contract had to be awarded by The Small Business Administration. In mid September, the contract was finally awarded. Contract N00189-76-C-0644 with Superior Engineering and Electronics Co., Inc. was a fact of life. The contract from start to finish had been completed in seventy eight working days. Ten days short of the "drop-dead" date of 1 October 1976.

CONTRACT TYPE

The required services have been broken down into two areas, i.e., management of the facility and direct labor effort (Item 0001AB).

The management portion shall be a firm fixed price for a period of 1 year based on a labor effort of 75 ($\pm$ 25%) direct production personnel. The direct labor effort will be on a cost plus award fee basis because it would not be possible at the time of contract award to know with any degree of certainty the level of work or amount of materials necessary to perform the required overhauls.

Both the Government and contractor will derive certain benefits from the combination of firm fixed price and cost plus award fee. Since the Government is providing the facilities, utilities, and special test equipment the contractor can estimate with a high degree of certainty the management effort needed to operate the facility. By considering the management portion on a firm fixed price basis a substantial amount of what usually would be considered overhead has been deleted. The contractor has incentive to control his management expenditures wisely and the Government saves on administrative effort by not having to verify management costs. The contractor is assured of recovering all allowable costs on his direct labor and will be awarded for accurate, timely, cost effective work.

The award fee will be based on the percent of work units (each unit to be repaired) completed on time, the percent of work units accepted on first inspection, and the percent of work units completed within the estimate. Each factor will be weighted as follows:

Timeliness - 50% Quality - 25% Cost Accuracy - 25%

The range of incentive effectiveness has been established to be 85 percent to 65 percent based on current experience of Government management of the facility.

Evaluation will be performed on a quarterly basis as follows:

1. $\dfrac{\text{Number of work units completed on time}}{\text{Number of work units issued}} \times 50 = (1)$ weighted percent

2. $\dfrac{\text{Number of work units accepted on first inspection}}{\text{Number of work units issued}} \times 25 = (2)$ weighted percent

3. $\dfrac{\text{Number of work units completed at or below estimate}}{\text{Number of work units issued}} \times 25 = (3)$ weighted percent

Each work assignment will normally consist of several work units but work units will be used in computing the award fee portion of the contract.

The summation of 1 + 2 + 3 equals the weighted evaluation percent. Each quarterly award fee will be calculated according to the following formula:

$$\frac{\text{Weighted Evaluation Percent (if greater than 65\%}}{85} \times \frac{\text{Total Award Fee}}{4}$$

If weighted evaluation percent is less than 65 percent, award entitlement is zero. Weighted evaluation percents greater than 85 percent will be considered as 85 percent.

Each work assignment issued by the Government will be estimated by the contractor as to delivery date and cost. The Government and contractor must agree on these estimates before commencement of any work. Any estimate changes must be agreed to by the Government. The agreed upon work assignment or modified work assignment will be the basis for the applied award for evaluation.

Cost Breakdown and Negotiation Results

As this is the first time that Superior has had a contract of this type, actual or estimated, cost factors in previous contracts do not exist. There are no known recent operating statements of the

proposed contractor for this type of work. An audit was conducted by DCAA Los Angeles. All contractor proposed rates were approved; however $30,000 of other direct costs were unsupported ($25,000 miscellaneous + 5,000 for a sign). Wages proposed are the current rates and are considered fair and reasonable.

The contract is broken down into two categories, i.e., administrative and direct production labor. Each category will be considered separate, and individual objectives were established by the procuring activity. The following breakdown is a summary and backup data for contractor's proposal and the negotiated agreement on the administrative portion. It was arrived at through consideration of the San Diego plan and the best estimate of the current Government management as to what capabilities would be required and what wages should be paid for the administrative personnel.

The aggregate management is composed of the following subcategories: Norfolk Management Personnel, California Management Personnel, Start up, Training, Travel, and other direct costs.

I. Management Effort (FFP)

			Proposed		Negotiated
A.	Norfolk Management Personnel		189,257		189,257
B.	California Management Personnel		84,487		72,046
C.	Start-up		51,313		15,055
D.	Training		33,570		18,951
E.	Travel		7,320		7,320
F.	Other Direct Costs		42,300		30,800
	Sub-total		408,247		333,429
G.	G&A @14.95%		61,033		49,848
	Sub-total		469,280		383,276
H.	Profit	(10%)	46,928	(8%)	30,662
			516,208		413,939

I. Comments on Direct Overhead

II. Direct Production Effort CPAF

This is the CPAF portion of the contract and provides for the direct labor production effort. The categories of labor to be used are as follows: Foreman, Electronic Mechanic, Electronic Worker, Electronic Helper, and Electronic Assistant. Based on an estimate of seventy-five man-years, a level of effort of 142,067 man-hours, including overtime, has been established. Position descriptions are included as part of the contract.

It is estimated that material and subcontracting work of approximately $400,000 will be required during the contract period.

The estimate of total cost for 75 (plus/minus 25%) man-years of direct production effort is as follows:

Direct Labor	$779,024
Overhead @ 25.8%	200,988
Overtime Pay	11,092
Material	400,000
SUBTOTAL	1,391,104
G & A @ 14.95%	207,970
TOTAL DIRECT COST	1,599,074
Base Fee @ 2%	31,981
Award Fee @ 4%	63,963
Total Cost	$1,695,018

The Electronic Maintenance Center currently charges its customers $16.00 per direct labor hour. This charge, exclusive of material, is also the current charge by Naval Shipyards doing this type of work.

In order to calculate cost per hour (exclusive of material) to the Government under the proposed contract, the following calculations have been made:

Management Cost	413,939
Total Est. Cost Plus Fee	1,695,018
Delete Material	400,000
TOTAL COST	1,708,957

To the total cost, exclusive of material, the Government's overhead must be added. It is estimated that overhead of $220,000 covering rent, utilities, Government personnel, etc. is an accurate figure.

TOTAL COST	1,708,957
GOVERNMENT OVERHEAD	220,000
TOTAL	1,928,957

Since the level of effort is 142,067 man-hours the dollar per man-hour is calculated as follows: 1,928,957 ÷ 142,067 = $13.58

Contractors in the local area performing this type of work in their own facility (at a level of approximately 150 direct production workers) typically charge between 12.00 and 13.00 per direct labor hour.

Since the management portion is fixed, as is the maximum fee, the $/hr. figure decreases as the level of effort increases. If the level of effort reaches 93 direct production personnel (the maximum under this contract) the cost per hour, exclusive of material, will be $12.50. These figures compare favorably to any open market situation and are substantial savings to the Government.

The basic concept driving the EMC operation is that price and workmanship must be of paramount importance. Each job received at the facility must be priced out completely and approved by the government prior to start of work. The basic flow of work thru the facility is as follows:

New Work → EMC Production Control (govt) → Contractor (Superior) → EMC QA (govt) → Return to Stock (govt)

NAVELEX Ports will have complete control over the contractor's workload, schedule and quality assurance.

One of the first steps that was taken after the contract award was to size up the competition. The following information was gathered and a copy was posted on all bulletin boards.

Activity	Hourly Rates
EMC Norfolk	$16.00
NESEC San Diego, CA	$16.00
NNSY Portsmouth, VA	$20.00
NNSY Portsmouth, New Hampshire	$20.00
NSY Charleston, SC	$20.00
OTHER LOCAL CONTRACTORS	$12.00-$20.00

It was absolutely necessary for the EMC Facility to keep its price below $16.00 per man hour.

The pricing structure for the facility and the proposed expansion plan worked out as follows:

MANNING	SUPERIOR OVERHEAD	GOVT	SUPERIOR LABOR	TOTAL COST
35	$6.85	$3.42	$6.79-$9.46	$17.00-$19.73
55	4.36	2.17	$6.79-$9.46	$13.32-$15.99
100	3.12	1.19	$6.79-$9.46	$11.10-$13.77
150	2.49	.80	$6.79-$9.46	$10.08-$12.75

From this chart, it was evident that as the workload increased and the fixed cost were spread over additional manhours, the total cost per manhour took a drastic drop. Using this as a selling point, EMC proceeded to expand its work and subsequently decrease its cost.

A quick study of our existing facility revealed that a work force of 100 people could be easily housed. Figure (I) was used as part of a presentation to show other commands our expansion capability.

Results To Date

Our 8(a) contract is in its eighty month. To date, the results have been very good. The facility employs 65 people. While this is slightly below the 75 level that was projected, it has maintained our manhour cost, at the $16.00 per hour level. The value of job orders approved to date by the government stands at $1,527,570. The workable backlog as of this date is 6.6 weeks and the scheduled backlog sets at 17 weeks. All very healthy signs for the EMC facility.

Many special projects have been successfully completed and the quality of the work produced has remained high.

It is interesting to note that an 8(a) firm has been able to compete head-on with other government activities and private firms from a cost standpoint. When the contract first started, NESEC Portsmouth was working only about 30 percent of the communications modules the supply center requested for stock. Gradually, we have built this up to where we now do 50 percent of these modules.

The reputation of the EMC Facility as a viable and cost effect electronics repair facility is growing. The work effort at the facility looks like it will double in FY78.

This contract effort solved three major problem areas for the Navy:

(a) It eliminated the need for additional ceiling points

(b) It placed work in the small business sector, more especially in the 8(a) sector

(c) It provided the Navy with a urgently needed product produced at a reasonable cost and of the required quality

From all points of view, this first eight months have been successful ones. The goal of NESEC Portsmouth is to assist Superior in every possible way so that the company can "graduate" from the 8(a) program (reach a level of experience and expertise where the SBA regards it as able to compete in the business world without special government assistance). Superior is rapidly approaching this point.

Lessons Learned

With any contract, 8(a) or otherwise, there are adjustments and problem areas that must be worked out after the fact. The time is rapidly approaching when a new contract for FY78 must be negotiated and let.

From past experience, NESEC Ports intends to modify the upcoming contract so that additional responsibility is placed on the contractors. Enough pricing information is now available to shift many of our repair efforts to a Firm Fixed Price contract. It has been suggested that new lines of work coming into the facility that lack adequate price information could be placed on an indefinite quality-time and material contract with Superior.

This first year contract is being used as a refinement stage to improve prices, services, and response time in succeeding contracts. The FY78 contract will be a big improvement over this contract, and the price and product will be further improved.

A Value Engineering clause will be added to the new contract. Awards/award fees granted under this program should be distributed in a manner which will promote participation by all contractor employees. If a man is held personally responsible for his work and knows that if he does an outstanding job he will be rewarded, his production and workmanship will improve. Delivery of a quality product in a timely manner is a basic requirement for any contract. Failure to correct those problems which result in substandard products or failure to maintain control of production problems should be cause to consider contract termination -- not just the loss of a few dollars in award fee.

CONCLUSIONS:

The latest figures show that about 9.42 million businesses in the nation are classed as small. They account for 43 percent of the entire gross national product. They employ 100 million Americans. From this point of view, there is nothing small about our small businesses.

The 8(a) program has received some bad publicity. In some instances, these complaints are justified. The original aim of the 8(a) program was to aid businesses run by the economically and socially disadvantaged. This principle is still a good one.

This does not automatically mean that the government should pay a higher price for less goods or services. To allow an 8(a) contractor to deliver less in quality or quantity than specified in the terms of the contract damages the small business firm as well as the government.

We all agree that there is a compelling national interest in assisting minority owned companies to break into the business world. As they prosper and become competitive, they in turn can provide employment opportunities for others. In the long run, this will lower unemployment and conserve the tax dollar.

In this particular contract, the contractor was given no special treatment that numerous other large corporations have not been given by the government in the past. They were made to bid on work rather than providing a direct handout. At all times, the quality of the finished product was certified by the government. Each and every phase of the contract effort was monitored and when price or workmanship took a lapse, corrective action was taken.

Superior Engineering and Electronics is a stronger company because they were made to compete in a real life environment and not in the artificial world of government subsidies. This contract has proven to me that 8(a) contractors can and will produce a quality product. If the DOD is really serious about providing assistance to minority companies, it will force 8(a) contractors to be responsible for their corporate actions, while to the maximum extent possible, provide help and guidance when needed.

This 8(a) contract is a success!

* EXPANSION CAPABILITY *

Personnel:

108 Work Benches Total

32 equipped for SRC-20/21 work
48 equipped for Electronic Warfare work
28 equipped for 2Z work

* Space available for 50 additional benches
* Cleaning area
* Miniature Repair capability with plans to add master micro-miniature station
* Establishing EW antenna repair area
* Small machine shop available with area for expansion
* Packing capability with expansion area
* Parts store room
* Technical library - now being established
* Parking available for approximately 90 cars
* Shipping and receiving area

Present physical plant can accommodate approximately a 100-man work force on a one-shift basis. This capability could easily be expanded to a 300-man force by tri-shifting.

Limitations:

(1) Cannot handle large antennas or equipments due to limited lift capability.

PROCUREMENT PRODUCTIVITY AND EFFICIENCY

THE MEASUREMENT OF PROCUREMENT PRODUCTIVITY IN THE US ARMY MATERIEL DEVELOPMENT AND READINESS COMMAND

Charles A. Correia
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INTRODUCTION

A. Background

In FY 72 Comptroller DARCOM established a productivity measurement system by developing an efficiency index with data extracted from the CAOMAF/Budget (Command Analysis of OMA Funding) system and other selected functional reports. In addition, Methods and Standards (M&S) Program data (formerly Defense Integrated Management Engineering System, DIMES) were also included to obtain a composite score reflecting how available resources are used by each manager. This measurement of efficiency was developed into a composite efficiency index for the depots and commodity commands within DARCOM. Five basic data elements (OMA dollars, workload, manyears, work standards, actual timed work) from the four functional areas of supply, maintenance, base operations, and procurement were used to develop productivity indices of dollars, manpower, and M&S performance efficiency. These indices were then combined into a composite efficiency index which measured each activity over time against itself and automatically weighted each functional area to the total resources of the activity. Effective in FY 76, the M&S data has been eliminated from the system.

The composite index compares like activities with respect to a base year to determine which activities are low in terms of efficiency improvement. Once these activities are identified, an attempt is made to determine the strengths/weaknesses which may be reinforced or improved to increase the activity's productivity. This concept has been working well at the depots and in several of the functional areas in the commodity commands. However, the procurement directorates of the Major Subordinate Commands (MSC's) have not felt the present productivity index relating their output to input is a true measure of the performance of the central procurement offices.

B. Problem.

The output measure for the workload of the procurement and production directorate of an activity is given in terms of procurement actions and procurement line items processed. The input measure is given in terms of manyears and cost expended identified in the Army Management Structure Code by PE 721113 to include .1, .2, and .3 categories; that is, manyears and cost expended in procurement operations, contract administration, and quality assurance. Herein lies the problem as judged by the procurement activities.

The output of a central procurement office is being measured in gross numbers so that the complexity of the output (a procurement action) is not taken into consideration. If a M&S Performance Efficiency Index had been or could be developed for the procurement activities, then perhaps some work standards for different methods of procurement might have been introduced. However, as it is yet not developed and there is some question as to the feasibility of its ever being developed, the present procurement productivity

index does not take into consideration the amount of man-effort required for different methods of procurement, dollar values, and types of contracts.

Secondly, it is felt that neither procurement actions nor procurement line items processed are the proper output measures to be compared with the input incurred under contract administration and quality assurance. There is a good deal of administration after contract award which cannot be charged against the procurement action. Additionally, since quality assurance is a product assurance function, it should not be included with the procurement workload.

C. Objective.

The objective of this report is then to develop a productivity index taking into consideration the amount of man-effort expended for different methods of procurement and types of contracts; and to examine ways of measuring the output associated with the amount of man-effort involved in the administration of a contract.

D. Scope and Method.

The AMCRP-127 central procurement workloading report presently records procurement work directives (PWD's) as to method of procurement and dollar threshold and as to whether they are cancelled or transferred prior to award. Since AMCRP-127 is already in existence and provides a source for reliable procurement productivity data, the productivity model has been developed around this central procurement workloading report.

Although time standards have been considered for different methods of procurement none are presently being used as established work standards. Since traditional work measurement methods do not appear to apply, a different, more subjective approach has been considered. Assuming it is possible to subjectively weigh the PWD's recorded in the AMCRP-127 report as to amount of man-effort necessary to award, then a meaningful output measure, functionally oriented to the procurement workload, may be considered.

Someone with years of varied experience in procurement may have some feeling as to the degree of man-effort needed to accomplish the award of a PWD and assign weights to PWD's commensurate with the amount of work involved. The weighted PWD's rather than simply total number awarded will then account for the output of a procurement and production directorate. A survey of 45 experienced contracting officers (those in grades GS-12 and above with at least 10 years experience in procurement) was made to estimate the respective weights of the PWD's. After a statistical analysis was performed on the weights assigned by the contracting officers who participated in the survey, the delphi technique was further applied to the mean weights to minimize the variability inherent in the survey. Since no established work standards are available for different methods of procurement and types of contracts, actual manhours per type of PWD are not directly measurable outputs; however, this does not mean that an estimated weight according to amount of man-effort required cannot be assigned.

In the case of identifying output for contract administration, the AMCRP-127 central procurement workloading report may again be used. The 127 report has a section which tracks the number of contractual type documents being administered for production and contract administration actions. If weights are assigned to each type of document (contracts, Board of Awards and Purchase Orders) then the total number of weighted documents may be considered as output to correspond to the input provide by the .2 category of PE 721113, contract administration.

This concept of weighted PWD's and types of contractual documents as output measures

and PE 721113.1 and .2 as input is used in this report to determine the procurement productivity index.

MEASURING PRODUCTIVITY

A. Present Method

The index in the functional area of procurement is the average of the manpower and dollar indices. The input factor for manpower is manyears expended under the Army Management Structure Code PE 721113 (AR 37-100-FY) to include the .1, .2, and .3 categories of procurement operations, contract administration and quality assurance, respectively. The constant (inflated) dollars expended for the 721113 code by an activity is the other input measure.

The output measures are procurement actions and procurement line items processed. What constitutes a procurement action is defined in AR 37-100-FY under the performance factor for procurement operations but essentially they may be considered as procurement work directives (PWD's) which have been awarded. Procurement Line Items Processed (LIP's) are the summation of the number of PWD's awarded, PWD's cancelled, and PWD's transferred.

Essentially, five steps are involved in the computation of the index:

a. Identification of outputs and inputs.

b. A workload relationship of line items processed to procurement actions given in percentages (such as 40/60, 50/50, 30/70) which each command assigns itself.

c. Computation of the weighing factor where the base year inputs (manyears expended or constant dollars) are divided by the base year outputs (workload in terms of LIP's and PA's) to obtain manyears per action or similarly dollar per action.

d. The outputs of each year are then multiplied by the relationship of LIP's to PA's and by the weighing factor in manyears which were both computed in the base year.

e. The weighted outputs for each year are then divided by the actual inputs (manyears expended and constant dollars). The mathematical form of the present procurement performance indicator is illustrated in Figure 1.

$$
\begin{aligned}
PI = \; & \frac{(\text{LIP's}) \begin{bmatrix}\text{Relationship of} \\ \text{LIP's to PA's}\end{bmatrix} \begin{bmatrix}\text{Weighting Factor} \\ \text{in Manyears}\end{bmatrix}}{\text{Manyears}} + \\
& \frac{(\text{PA's}) \begin{bmatrix}\text{Relationship of} \\ \text{LIP's to PA's}\end{bmatrix} \begin{bmatrix}\text{Weighting Factor} \\ \text{in Manyears}\end{bmatrix}}{\text{Manyears}} + \\
& \frac{(\text{LIP's}) \begin{bmatrix}\text{Relationship of} \\ \text{LIP's to PA's}\end{bmatrix} \begin{bmatrix}\text{Weighting Factor} \\ \text{in Dollars}\end{bmatrix}}{\text{Dollars}} + \\
& \frac{(\text{PA's}) \begin{bmatrix}\text{Relationship of} \\ \text{LIP's to PA's}\end{bmatrix} \begin{bmatrix}\text{Weighting Factor} \\ \text{in Dollars}\end{bmatrix}}{\text{Dollars}}
\end{aligned}
$$

PRESENT PROCUREMENT INDEX - FIGURE 1

The example in Figure 2 uses the mathematical relationship of Figure 1 to explain the computations involved in arriving at a procurement productivity index for a major subordinate command. The outputs for each succeeding year after the base year are multiplied by the weighting factors established in the base year 72. The weighted outputs for each year are then divided by the actual inputs to arrive at productivity indices for manpower and dollars. The manpower and dollar indices are then averaged to obtain the procurement index. The procurement index is equal to one for the base year and then will be greater than, less than, or equal to one in the following years, indicating an increase, decrease, or no change, respectively, in procurement productivity. The same procedure is used to calculate indices for the functional areas of supply, maintenance, and base operations. These indices are then combined into the composite efficiency index. Note that although a weighted output is computed, it is not weighted to the amount of man-effort involved as to the method of procurement or type of contract employed to arrive at a procurement action In addition, there is a double counting involved since the procurement line items processed includes PWD's awarded which are equivalent to procurement actions.

Whereas the present method employed by Comptroller to arrive at a productivity index may work well for depot maintenance operations, which are greatly conducive to M&S usage since they are production line type operations, providing meaningful data down to the component/subassembly level, the major subordinate command's procurement operations measure only summary level data: i.e., number of procurement actions and number of line items processed. In addition, some of the input used to arrive at the procurement productivity index does not correspond to the proper performance factor. The input used under the .2 and .3 codes (contract administration operations and quality assurance for central procurement activities) have "contracts requirement production action" and "dollar value of material inspected and released for shipment", respectively, as their performance factors, not procurement actions and procurement line items processed.

Therefore, in order to be fair to the central procurement activities a new procurement productivity index should be employed which relates the proper output to the input provided by the .1, .2 and .3 codes of AR 37-100-FY and measures the man-effort employed by each different method of procurement which M&S has been unable to do.

B. New Method.

1. Introduction. This report concentrates on the reliability and quality of the output measure. Output should be able to be easily counted consistently year after year. It should be mutually exclusive of any other output so that double counting will be avoided. It should be the final product (or an intermediate product contributing to the final product) of a significant group of workers whose time and costs can be directly identified with the output. In a service organization it is often difficult to identify with the final product. For example, in a maintenance hangar it is easy to identify the final product as a repaired aircraft; however, it is more meaningful to distinguish between aircraft such as bombers, fighters, trainers, and helicopters. Each different type aircraft requires more or less time and skill, hence, an attempt should be made to differentiate and weight the output according to the effort needed to produce it. This concept holds true for the workload in a procurement directorate as well as in a maintenance hangar.

Not all procurement work directives (PWD's) entail the same amount of manhours to award. The amount of manhours to award a contract or process a PWD may be explained by the distinction of such complexity factors as the dollar amount, the method of procurement, and the type of contract applied for the proposed award. Therefore, the use of total number of PWD's processed as an output measure fails to differentiate as

Inputs	Base Year			
	72	73	74	75
1. Manyears .1,.2,.3.	900	800	750	700
2. Dollars	15,500	15,000	13,500	13,000

Outputs	Base Year			
	72	73	74	75
3. Workload				
Line Items Proc.	17,000	18,000	16,000	15,500
Procurement Actions	5,500	9,500	9,000	11,000
Relationship	.5			

4. Weighting Factor

a. Myrs: LIP 900/17,000 = .05294

PA's 900/5,500 = .16364

b. Dols: LIP 15,500/17,000 = .91176

PA's 15,500/5,500 = 2.81818

5. Weighted Output

		72	73	74	75
a. Myrs:	LIP	450	476	424	410
	PA's	450	777	736	900
	Total	900	1,253	1,160	1,310
b. Dols:	LIP	7,750	8,206	6,154	7,066
	PA's	7,750	13,386	12,682	15,500
	Total	15,500	21,592	18,836	22,565

6. Productivity Indices

	72	73	74	75
Manpower (Wt Output/Manyrs)	$\frac{900}{900} = 1.000$	$\frac{1,253}{800} = 1.566$	$\frac{1160}{750} = 1.547$	1.871
Dollars (Wt Output/Dollars)	$\frac{15,500}{15,500} = 1.000$	$\frac{21,592}{15,000} = 1.439$	$\frac{18,836}{13,500} = 1.400$	1.736
7. Procurement Index	$\frac{1+1}{2} = 1.000$	$\frac{1.566+1.439}{2} = 1.503$	$\frac{1.547+1.400}{2} = 1.474$	$\frac{1.871+1.736}{2} = 1.804$

EXAMPLE COMPUTATIONS OF PROCUREMENT INDEX

Figure 2

to the quantity/quality of man-effort required for each type of PWD.

2. Procurement Operations. The performance factor which is felt to be more representative of the workload output to a central procurement office is procurement line items processed. Procurement line items processed are made up of procurement work directives processed to award, cancelled and transferred. These PWD's cover the entire workload area for procurement operations.

a. Procurement Work Directives Awarded. While a PWD which has been awarded is equivalent to a procurement action, gross numbers of procurement work directives by themselves do not explain the amount of work involved in each PWD. Currently, AMCRP-127 Central Procurement Workloading Report lists the number of PWD's awarded by dollar thresholds and methods of procurement. A program change by the Army Logistics Management Systems Agency (ALMSA) is planned to include type of contract in the current report of the Procurement and Production Subsystem of the Commodity Command Standard System (CCSS).

There are no generally established standards for the number of manhours required to award a PWD; therefore, manhours per type of PWD do not exist. However, this does not preclude the possibility of subjective weighting of PWD's according to the amount of man-effort felt to be involved in their award. A survey was made up geared to the AMCRP-127 report. Eight methods of procurement were listed in survey categorized by dollar value (under $10,000, $10,000 and over) and type of contract (fixed price or cost). Experienced personnel throughout DARCOM were asked to weight the different methods of procurement according to dollar size and type of contract. Ten percent of the weights were excluded - five percent at each end of the distribution. After a statistical analysis of the data, the delphi technique was used to refine the mean weights so as to minimize the variability inherent in any survey of this type.

b. Procurement Work Directive Cancelled. Oftentimes a PWD requires a great deal of man-effort but does not result in an award. That is to say, a requirement is given to procurement personnel for a particular item, and the personnel proceed to procure the item. After all the necessary work has been done and all that is left is to sign a contract, the requirement is cancelled for reasons which are no fault of the procurement personnel (lack of funds or the requirement itself is cancelled). The amount of man-effort expended never results in award, but is still part of the procurement workload. Naturally all PWD's do not proceed in time up to the point of award before they are cancelled, but may instead be cancelled after 5%, 25%, 50%, or 75% of the total man-effort to award has been expended.

Cancelled PWD's may represent a significant amount of a procurement directorate's workload. An obvious answer to the problem of cancelled PWD's is to better manage the requirements and budgeting of funds. However, the control of these functions is external to the procurement directorate and it is not appropriate to measure a procurement directorate for something over which in most cases they have no control. By the same token it would be inappropriate to allow the total number of cancelled PWD's to be converted as output if only 5%, or 25% of the amount of man-effort needed to award is expended. Hence, based on a review of cancelled PWD data and perceptions of command personnel, a figure of 50% is used to balance the expenditure of the time between those cancelled PWD's requiring more man-effort. If up to that point in time until a PWD is cancelled, the amount of work involved in each is still determined by the complexity factors of the method of procurement, dollar value, and type of contract, then each cancelled PWD should be weighted equivalently to the one which is awarded. However, only 50% of those PWD's reported as cancelled with a designated method of procurement and type of contract will be counted as a weighted output.

The current AMCRP-127 Central Procurement Workloading Report lists the number of cancelled PWD's with a designated dollar threshold and method of procurement. A program change is planned to include type of contract.

c. Procurement Work Directives Transferred. The third category of procurement line items processed are procurement work directives transferred either as Military Interdepartmental Purchase Requests (MIPRS) to other services or other similar documents utilized to transfer the procurement requirements to other commands, installations, or activities. In some commands the number of PWD's transferred make up a significant portion of their workload. The greater the dollar value the more monitoring is required. Although the amount of man-effort required is not as great as that necessary for award of a PWD, time and effort are expended and hence should be weighted accordingly in the output portion of a procurement productivity model. Those commands whose workload contain a significant amount of transferred PWD's were consulted for comparison between PWD's awarded and transferred. Their comments were evaluated and weights were assigned employing the delphi method by personnel external to the commands consulted. The current AMCRP-127 Central Procurement Workloading Report lists the number of PWD's transferred by dollar threshold.

2. Contract Administration. A great deal of man-effort is expended by a procurement directorate in the area of contract administration. In the present productivity model, this man-effort has been credited to the procurement directorate in the form of input; i.e., it is recorded in the .2 category of the Army Management Structure Code PE 721113, and used along with the man-effort expended in the .1 and .3 categories. However, the output performance measure used to explain the .2 input is the same as that to explain the .1 input for procurement operations; i.e., procurement line items processed and procurement actions. A great deal of work is expended after the award of a contract which is not explained by present performance measures. If any procurement productivity model is to be meaningful, an attempt should be made to incorporate a reliable performance factor which credits that percentage of the procurement directorate's workload dealing with contract administration to the output portion of the model. If this cannot be done, then the .2 category of PE 721113, Contract Administration, should not be included as input as is presently done.

A performance factor for the .2 category is defined in AR 37-100-FY as "contracts requiring production action," but it is not used in the present model. However, if it is used, the same argument exists here as did for procurement actions, and that is that all contracts do not require the same amount of work and hence should not be treated simply in terms of gross numbers. There are some simple documents to administer such as purchase orders, delivery orders, basic ordering agreements (BOA's), and then there are contracts such as production versus R&D. The amounts of man-effort involved in administering these documents will differ. Therefore, it is logical to weight each type of document depending on the expenditure of man-effort required to administer. The AMCRP-127 Central Procurement Workloading Report, lists the number of purchase orders, delivery orders, BOA's, and contracts both in productions actions and contract management actions taken. Weights for each type document were solicited from contracting officers throughout DARCOM. Their comments were recorded, evaluated and then subjected to the delphi technique.

3. Quality Assurance. The man-effort expended under the .3 category of PE 721113 should not be evaluated by the performance factor for procurement operations or contract administration. The opinion of this report is that any input expended in the .3 category of quality assurance should be accountable by the Directorate for Quality Assurance and not Procurement and Production, since quality assurance is a product assurance function. In addition, the P&P Directorate does not have functional control over quality assurance personnel, and no output measures to account for their input,

hence, quality assurance should not be included with the procurement workload.

C. Differences Between Present and New Method.

The primary difference between the new method for measuring productivity and the present is the use of weighted PWD's awarded, cancelled, and transferred in place of total line items processed, and the use of weighted contractual type documents instead of total procurement actions. In addition, the only input which will be used in the productivity model, both in manyears and dollars, will be that provided in the .1 and .2 categories of PE 721113. The quality assurance input, .3 category, will be dropped, and there will be no further need for any relationship factor of LIP's, to PA's as there is in the present indicator (recall figure 1). The proposed performance indicator will take on the form in figure 3, where PWD's$_A$, PWD's$_C$, PWD's$_T$, are procurement work directives awarded, procurement work directives cancelled and procurement work directives transferred, respectively; and KD is the number of contractual documents having production and contract management actions applied thereto.

$$\frac{\left[\sum Wt\ PWD's_A + \sum Wt\ PWD's_C + \sum Wt\ PWD's_T\right]\left[\text{Weighting Factor in Manyears}\right]}{\text{Manyears}} + \frac{\left[\sum Wt\ KD\right]\left[\text{Weighting Factor in Manyears}\right]}{\text{Manyears}} +$$

$$\frac{\left[\sum Wt\ PWD's_A + \sum Wt\ PWD's_C + \sum Wt\ PWD's_T\right]\left[\text{Weighting Factor in Dollars}\right]}{\text{Dollars}} + \frac{\left[\sum Wt\ KD\right]\left[\text{Weighting Factor in Dollars}\right]}{\text{Dollars}}$$

PROPOSED PROCUREMENT INDEX - Figure 3

The example in Figure 4 illustrates the new methodology of the proposed procurement index. Note that it is now possible to separate and analyze output and input with respect to procurement operations and contract administration; in addition, the dollar breakout is much more visible. Consequently, if desired, separate productivity indices may be kept on procurement operations and contract administration and be used by management in the P&P Directorates.

Apart from serving as input to the Comptroller composite efficiency index, this model may be used by the P&P Directorate action officers as a tool in the management of their respective objectives. The AMCRP-127 report maintained by personnel in the P&P Directorate serves as the primary data base for the model. Only input data for the dollar productivity index requires data provided by the Comptroller Approved Operating Budget, CSCFA-218 Report. All other data for both manpower and dollar indices is provided by AMCRP-127. The following Table I explains where the data is found in the 127 report and what portions are presently in the CCSS system. In addition, the model will make readily available the distribution of workload as to procurement operations (broken out as to PWD's awarded, cancelled, and transferred) and contract administration

Inputs		Base Year 72	73
1. Manyears			
a. Proc. Ops.		400	300
b. Cont. Adm		200	300
	Total	600	600
2. Dollars			
a. Proc. Ops.		1,000,000	800,000
b. Cont. Adm.		500,000	500,000
	Total	1,500,000	1,300,000
Outputs			
3. Workload			
a. Proc. Ops.			
$\sum$ Wt PWD's$_A$		10,000	9,000
$\sum$ Wt PWD's$_C$		5,000	4,000
$\sum$ Wt PWD's$_T$		500	400
	Total	15,500	13,400
b. Contract Adm.			
Wt KD		50,000	60,000

4. Weighting Factor

a. Myrs:	Proc. Ops.	400/15,500 = .0258	
	Cont. Adm.	200/50,000 = .0040	
b. Dols:	Proc. Ops.	1,000,000/15,500 = 64.5161	
	Cont. Adm.	500,000/50,000 = 10.0000	

5. Weighted Output

a. Myrs:	Proc. Ops.	400	(13,400)(.0258) = 346
	Cont. Adm.	200	(60,000)(.0040) = 240
b. Dols:	Proc. Ops.	1,000,000	(13,400)(64.5161) = 864,516
	Cont. Adm.	500,000	(60,000)(10.0000) = 600,000

6. Productivity Indices

a. Manpower

(Wt Output/Myrs) (400+200)/600 = 1 (346+240)/600 = .9767

b. Dollars

(Wt Output/Dollars) $\frac{(1,000,000)+(500,000)}{1,500,000} = 1$ $\frac{(864,516)+(600,000)}{1,300,000} = 1.1266$

7. Procurement Index $\frac{1 + 1}{2} = 1$ $\frac{.9767 + 1.1266}{2} = 1.0516$

EXAMPLE ILLUSTRATION OF NEW PROCUREMENT PRODUCTIVITY INDEX

Figure 4

Table I

DATA SOURCE

OUTPUT — INPUT

Procurement Operations - 721113.1 (In ALPHA System)		Contract Administration - 721113.2 (Not in ALPHA System)		Manpower (Not in ALPHA System)	Dollar	
PWD's		Contractual Documents				
Awarded	127 Part I, Section A, Lines 4 & 10; columns a through h	Prod	127 Part II, Section A, Line 3;: columns a, b, c, and d	Proc Oper - 127 - Part IV 721113.1 Section A	Proc Oper 721113.1	CSCFA-218
Cancelled	127 Part I, Section E, Lines 20, 21, 24, 25; columns a through h					
Trans-ferred	127 Part I, Section F, Lines 28 and 31; columns a and b	Contract Mgmt	127 Part II, Section B, Line 7; columns a, b, c, and d	Cont ADMIN - 127 - Part IV 721113.2 Section B	Cont Admin 721113.2	CSCFA-218

(production and management).

(Initially, the dollar breakout was to be under $10,00 and over $10,000; however, upon critique of the study several reviewers thought a better weight distribution could be developed if the dollar breakout consider $10,000 to $100,000, and over $100,000. The reason this breakout was not employed originally was that the AMCRP-127 report only considered method of procurements under $10,000 and over $100,000, and it was already automated in CCSS. However, since the addition of the third dollar category is considered to be most beneficial to the productivity model, it will be included in the AMCRP-127 report and hence in CCSS. When this report is published by APRO the weight distribution is to method of procurement, dollar threshold, and type of contract will be included.)

WORKLOAD ASSESSMENT AND MANPOWER APPORTIONMENT IN DCASR BOSTON'S PRODUCTION DIRECTORATE

Harry A. McCormick
Defense Contract Administrative
Services Region - Boston

It is indeed an honor and pleasure to speak to you today. This morning I want to discuss with you some concepts which we have developed in DCASR Boston's Production Directorate which relate to the identification of workload elements and consequently the distribution of personnel resources to our operational work locations.

Procurement manpower planning represents an on-going and extremely important managerial responsibility applicable to all elements of the material acquisition cycle. Today's environment places Department of Defense procurement managers in the challenging position of trying to deal effectively with a more sophisticated and demanding procurement workload while generally faced with declining manpower resources.

The Defense Contract Administration Services (DCAS) of the Defense Logistics Agency (DLA) places much emphasis on manpower planning in order to provide the most effective and efficient contract administration services for the procurement agencies which we serve. While the need for effective manpower management certainly encompasses the broad procurement spectrum, involving many agencies and activities, this presentation will attempt to illustrate the challenge by focusing on production manpower management in a large DCAS Region in this case, the Boston Region.

Prior to my discussion of the workload measurement concepts and their application, I will take a few minutes to describe:

SLIDE #1 ON

(1) The organizational relationship of DLA and DCASR Boston.

(2) Then specifically, DCASR Boston's organization and its production element, then I will briefly

(3) Give an encapsulated review of the major production functions performed.

(4) Discuss workload statistics for the region and the production directorate in order to give you a "feel" for the magnitude of the business volume.

(5) I can then discuss my experiences and observations of workload and related manpower measurement using earlier methods which lead to the development of our current methodology and its application.

SLIDE #2 ON

The Director of the Defense Logistics Agency, Lieutenant General W. W. Vaughan, USA, has twenty-four major field activities reporting to him: 6 Supply Centers, 4 Depots, 5 Service Centers, and 9 Defense Contract Administration Services Regions. The Deputy Director for Contract Administration Services Regions is Major General Vincent H. Ellis, USA. The Boston Region's Commander is Captain T. J. Mulligan, USN, the Director of Production is Mr. Ralph Kabureck.

SLIDE #3 ON

DCAS Regions are structured in a straight forward two level organizational concept consisting of the region headquarters and its subordinate field operating elements. The field elements consist of Defense Contract Administration Services Management Areas and Plant Representative Offices referred to as "DCASMs" and "DCASPROs". Both types of operational field activities are assigned similar missions; have equal organizational status with their respective commander reporting directly to the region commander: and differ mainly in regard to geographic territory assigned and the number of contractors with which they interface.

SLIDE #4 ON

DCASR Boston has twelve field activities - 7 DCASMAS and 5 DCASPROS. Each of these offices has an integral DCAS production management operational element in the form of a production division.

SLIDE #5 ON

DCASR Boston, as a primary field level activity of the Defense Logistics Agency, is responsible for all contracts delegated by procurement agencies for contract administration services within upstate New York and the six New England states. It serves procuring activities principally through the field management of contracts including the performance of those administrative functions defined in ASPR 1-406.

SLIDE #6 ON

Briefly, the primary functions supporting the DCAS production mission are carried out by industrial specialists, engineers and other professionals. These people participate in pre-award surveys of potential contractors which determine whether the offeror is qualified to produce in accord with the terms and conditions of the solicitation before a contract is awarded. Once the award is made, surveillance is maintained over the contractor's progress toward meeting delivery dates; delays are reported and any corrective action that is needed is taken. When necessary contractors are assisted in obtaining priorities for critical materials. In addition a digest is published

annually that facilitates the exchange of manufacturing cost control ideas among defense contractors.

Surveys are conducted to assure that government owned plant equipment in use by defense contractors is efficiently utilized and that adequate maintenance is provided for government owned plants.

SLIDE #7 ON

The production organization also conducts surveillance to assure compliance with Environmental Protection Agency regulations in regard to air, noise, and water pollution for government owned facilities located within the region.

Surveys are performed for industrial preparedness planning requirements from claimant activities to assure an adequate industrial production capability in the event of national mobilization or a limited war.

A voluntary program with industry to maintain energy conservation is accomplished in cooperation with the Federal Energy Administration, Department of Commerce, Defense Contract Audit Agency, state and local governments. Included in DLA's energy program are fuel shortage assistance procedures to assist contractors in obtaining fuel allocations adequate to meet essential defense production requirements. Defense Logistics Agency production related activities include engineering surveillance and assistance.

SLIDE #8 ON

Evaluation of proposed engineering changes and maintenance of a value engineering program. Technical support to program managers is provided through DCAS surveillance of cost/schedule control systems program contracts and special emphasis programs and technical analysis of cost proposals.

SLIDE #9 ON

Other services include monitoring by industrial labor relations specialists of actual and potential strikes at contractor plants: coordinating removal of critical defense material from strike bound plants: and services related to the enforcement of labor standards and industrial manpower requirements.

SLIDE #10 ON

Transportation and packaging specialists assigned to the production organization assure on-time shipments of damage free material via the most economical means of transportation. Their work includes technical assistance to contractors: Issue and control of Government bills of lading, and other transportation documentation.

SLIDE #11 ON

The Boston DCASR has some 2,900 contractors of which 1,700 are active in any given period, with approximately 30,000 contracts. The face value of these procurements is 12 billion dollars with an unliquidated value of 5 billion dollars and a daily disbursement of 12.5 million. The DCASR manning level is currently 2,355.

SLIDF #12 ON

You will notice that the production statistics are in all cases less than the region's statistics. This is due to the fact that not all contracts administered by the region have production administration services delegated.

The production directorate is presently authorized 362 civilian positions. The contract population under production surveillance is 22,000 with 1,500 active contractors with an obligated value of 9.7 billion and an unliquidated value of 3.5 billion.

Of the 362 authorized positions, there are some 37 distinct occupational disciplines and/or separate grade levels within our production organization, which are distributed among 12 operational organizations and the region headquarters staff, which illustrates, to some degree, the complexity and challenge of effective manpower management.

My personal experience includes service in both a large area office and two plant offices. During my tenure at these offices, it became evident to me that certain distinct differences in the nature of the work, due to the types of contracts being administered, was apparent. Our product, production services to our customers, and volume of work is no doubt driven by the number of contracts we receive. This primary workload indicator did not in my opinion reflect the degree of complexity associated with the different offices.

Work patterns are formulated by the nature of the contract mix and associated contract characteristics of each of the two operating environments, area and plant offices, which appears to be somewhat of a dichotomy. Area offices stressed the wide variety of commodities and large number of contracts which they had to administer, while plant offices emphasized the higher dollar value of their contracts and the generally more sophisticated systems or sub-systems involved. The primary workload indicator was the contract population for each office, stratified by a categorization system, and an associated average: A lower one for an area office and a higher one for a plant office.

Essentially, the DCASR authorized strength is determined by the DLA Comptroller and allocated by function cost account to the Region Commander who has the authority to make necessary adjustments or resource trade offs among the various functional specialties. The charter for manpower planners then is to determine workload requirements in distinct quantifiable terms, recognizing the different operating environments, yet somehow define them in a way which would be common to both areas. The available

authorized positions can then be distributed to the twelve operating activities and the regional staff organization, adjusting them as workload fluctuates.

These workload measurements must be realistic and therefore, have the confidence of both the planners and the operating officials for acceptance and balancing of conflicting conditions; yet be sufficiently abstract to use for all locations in making equitable manpower distribution.

Because of the nature of DCAS business, essentially performing a variety of services for the procuring activities, or servicing the contracts we receive and assume therefore most of the work effort is associated with these contracts, it behooves us to know as much about them as possible.

If we can reduce a contract to its basic terms, dissecting its elements like therbligs, which drive work tasks we can analyze them, rebuild "typical" contracts, discern delta differences between locations and assess their impact on manning requirements and distribution.

Recognizing that much of our record maintenance is contained without computer system and is sorted in many different ways, our information storage and extrapolation capability is greatly expanded vis a vis prior manual systems. We are only limited then by our data systems and realistically with any new programming costs.

As a staff planner, I have had an opportunity to reflect upon these conditions and challenges and propose what I call the "production contract attribute system" which indeed is certainly not a panacea. I believe it is a more realistic approach with greater depth than the contract count and averaging method used previously. Additionally DCASMA/DCASPRO commanders and division chiefs have been receptive to this approach.

DLA has a work measurement system known as the Defense Integrated Management Engineering System (DIMES). The system for workload and resources management, which I will review, does not conflict with the DIMES program; conversely, it identifies work attributes by contract distribution which should enhance the program.

The six characteristics I will address focus on contract aspects that will enable us to analyze and recognize office location workload characterized by relatively few contracts but requiring significantly more manpower than would be indicated by the previous method. Analyzing our contracts from a production standpoint leads to the conclusion that the number of line items involved and frequency of delivery schedules are potential candidates for further investigation. These factors are what we "track on" during our production surveillance effort and therefore are instrumental in defining actual workload.

DIMENSION 1 AND 2

We produce various ADP products which are sorted by line item and this data is readily available for study as one dimension of our analysis. Let us abstract for our twelve operating locations both the empiric number of line items and the percent distribution to total using a homogeneous or family grouping for the DCASMAS and DCASPROS.

Frequency of schedule is (a) Perhaps not as significant an element if we assume that once the line item is identified and established the degree of difficulty associated with its surveillance is of considerably less value than the line item itself, (b) Our current ADP system does not identify individual schedules which are past due. Future schedules can be identified and factored with future lines to determine schedule frequencies.

DIMENSION 3 & 4

Contract population is still a valid and important dimension of individual office workload. Analyzing it closer, the dwell time or contract turnover rate is an aspect which also requires investigation for a meaningful and comprehensive workload analysis. An appropriate analogy from a business or profit oriented perspective is if we owned our own retail establishment we would certainly be interested in first the cost price mark up by product and second the shelf turnover rate...for its effect on profits and cash flow, not unlike the shelf turnover rate is the contract turnover rate. Numerous common fixed work efforts/tasks, like fixed costs, are associated with every contract. If, in fact, there are significant variations from location to location, then this dimension bears investigation.

Contract turnover rate can be measured in two ways: First by taking all contracts completed during a specified time period and dividing by the average number of contracts on hand for that same period...preferably a year to avoid cyclical peaks and valleys and also for yearly correlation to the manyear concept. The second method of contract turnover rate can be accomplished by a computer scan of aggregate active contracts life cycle in calendar days, computed from the effective date of the contract measured to the final delivery date or forecasted final delivery date, whichever is later, divided by the number of contracts by location for the average contract life time.

Using method number one, an advantage of actual history is realized. Utilizing method number two, an instataneous camera's view is obtained; however, contract extensions for a variety of reasons, could possible distort actual historic patterns. An initial correlation study of these two methods did show a deviation.

I have elected to use method number one because of t e higher degree of confidence realized with the historic data.

For method number one, using a one-ye r period, an index can be developed which will allow us to convert the actual contracts on hand to the equivalent contracts on hand due to turnover. For example:

SLIDE #13 ON

$$\frac{\text{CONTRACTS COMPLETED}}{\text{AVERAGE CONTRACTS ON HAND}} = \text{INDEX}$$

INDEX TIMES ACTUAL CONTRACTS ON HAND EQUALS CONTRACT EQUIVALENCY

$$\frac{25,000}{22,000} = 1.14$$

$$1.14 \times 24,000 = 27,360$$

LET US TAKE AN OFFICE WITH THE REVERSE NUMBER FOR A COMPARISON ON MEASURED EFFORT.

SLIDE #14 ON

$\frac{22,000}{25,000}$ = .88

.88 X 24,000 = 21,120

27,360 - 21,120 = 6,240

$\frac{6,240}{21,120}$ = 29.54%

IF ALL OTHER WORK DIMENSIONS WERE THE SAME IN OUR HYPOTHETICAL SITUATION, THIS WOULD BE A SIGNIFICANT WORKLOAD CHARACTERISTIC.

Reference back to method number two, the contract turnover rate index can be determined by dividing the average contract life in days by 365. The contract equivalency is determined by multiplying the index by the actual contracts on hand, for example:

SLIDE #15 ON

$\frac{365}{344}$ = 1.06

1.06 X 24,000 = 25,440 AGAIN TO COMPARE A REVERSED STATISTICAL SITUATION

$\frac{365}{386.9}$ = .94

.94 X 24,000 = 22,560

25,440 - 22,560 = 2,880

$\frac{2,880}{22,560}$ = 12.77% AGAIN ALL OTHER DATA REMAINING THE SAME A SIGNIFICANT DEVIATION.

Dimension number five, the dollar value of the contracts managed is another important factor to be considered in our total business assessment. When contract value is associated with the quantity and mix of line items, it can provide an indication of the relative complexity, particularly when comparing our operating offices location to location. This workload characteristic can be measured in two ways, using either obligated or unliquidated contract dollar value. I prefer the latter, since it portrays the balance to be delivered and hence relates to both current and future workload.

The sixth and final factor to be considered is the number of active contractor production facilities under the cognizance of a particular office location. This dimension gives us an indication of diversity or breadth of workload when again comparing office to office. A further refinement in program calculations could show distribution by density which would be helpful in our assessment considering wide geographic distances between facilities versus another location which had relatively confined or close geographic distribution.

The six characteristics which I have briefly reviewed are contained within current ADP programs and are therefore retrievable without establishing new data programs.

In order to more clearly understand the comparative relationship of the twelve locations, using the above characteristics, a matrix containing the relevant data is used for a specific time period as we would in accounting terms with a balance sheet or cost of manufacturing, to use as an illustration of the analysis.

In this instance, we will use 30 April 77 statistics. The maintenance of characteristics is rather "busy". As you can see, five of the dimensions have both the empiric number and the percent to total columns. In order to more clearly show the effect of the characteristics on one slide, the next slide will drop the empiric numbers.

SLIDE #17 ON

For comparison purposes, family grouping of area offices and plant offices were structured accordingly, i. e. the first seven offices are area and the remaining five are plant offices. Now our collective demographic data is ready for an analysis for workload patterns.

In order to more clearly portray some specific comparisons the next slide will explode and isolate four dimensions for three offices.

SLIDE #18 ON

Comparing actual contracts with the contract turnover equivalency, we can see in some instances dramatic variation as with the Rochester to GE Burlington offices greater than three to one.

The line item and unliquidated percent distribution present a rather different picture as you can readily see. Raytheon and GE Burlington stand out as high value locations or complex types of product.

SLIDE #19 ON

The next slide adds to the percent characteristics the operational manpower by location.

I draw your attention to the "authorized positions" column and the "adjust for T&P" column. Currently, we have limited our transportation and packaging operating divisions to four, however, these four elements provide transportation and packaging services and support throughout the region. In effect they serve all twelve operational locations. This anomaly required an adjustment to the actual manpower authorized, the last column, to prorate the man year effort of the servicing office and offices being served.

One can readily see the variation by characteristic, office by office, but collectively the workload characteristics are relatively balanced.

On two relatively recent occasions, significant authorized manpower reductions were mandated and were accomplished on the basis of this analysis. We were initially faced with somewhat irate operating officials ready to request reassessment. When, however, this rationale and methodology was used and explained, the line operating elements accepted the retrenchment decisions as being equitable and reasonable! I emphasize that no quantifiable formula was used except workload patterns, trends, and experienced judgment. Authorized position distributions were then adjusted based on the results of this comprehensive data assembly and analysis.

Earlier I mentioned the Defense Logistics Agency Integrated Management Engineering System more commonly referred to by the acronym "DIMES". This system conforms to DOD Directive 5010.15 which establishes a requirement for management engineering skills in the military departments and defense agencies. Simply stated, DIMES uses the expertise of trained management engineers to determine how long it should take (not how long it might take or how long it use to take) to perform tasks that need to be done and to establish standards by which an organization's manpower efficiency can be measured, and to seek out more efficient ways of accomplishing tasks. Once the management engineer has done his job, the results are made part of the data base in a management information system whether it be a sophisticated automated type or a stubby pencil type.

The common responsibility for defense managers and supervisors who are responsible for the effective and economical use of their manpower resources is to measure and improve productivity and make proper use of productivity changes. From the perspective of an operating manager during the evolutionary development of DIMES some difficulties were encountered.

In the early stages of DIMES implementation, "engineered" standards were developed and set at a particular location and subsequently applied to another location. One work center had two primary points of workload count: contracts received, and contracts completed and closed out. The work standard for contract closures was greater than contract receipts. As an operating supervisor, I found myself in the unenviable situation of realizing an increase in contracts, more receipts than closures, with an inefficient productive hour condition, a summary indication that my staff was too large when actually the reverse was true.. Needless to say, the standards were eventually adjusted to accommodate the actual workload conditions.

Subsequently engineered standards were developed for each location. Albeit this was an improvement from the earlier methodology it left unexplained why standards differed from location to location for apparently similar tasks. Furthermore, it did not allow correlation comparisons, particularly from the national viewpoint.

DLA is currently in the process of establishing national standards which would be applicable to all and any cost center of a similar nature. This study is known as the special purpose data or SPD. The SPD standards are using optimistic, pessimistic, and most likely time aspects with one time selected.

It is certainly not my intention to either demean any current efforts such as the special purpose data study or the people who are working so assiduously to make them a success but conversely to contribute to their success. The problem I perceive with this method is wide deviations from the standard could cause apparent non-productive conclusions when in fact there were valid deviations due to differing workload conditions and quantitative differences of tasks which were not measured in establishing the standards.

If, however, engineering standards were developed on some of the abstract measurements I have discussed today, several advantages, in the author's opinion would be gained.

First, the universal work measurement standards would be facilitated because they would be based upon criteria which would be associated with contracts at a base line that identifies micro work elements keyed to actual demographic distribution.

Secondly, it would accommodate different workload mix situations with wide deviations at all locations.

Centralized control of the standards could be maintained. As operational methods change necessitating revisions to existing standards or the establishment of new standards, the central focal point with the complete statistical universe would logically make these determinations.

Standards established on the characteristics discussed would promote the use of ADP systems as the product of the standards and dimensions divided by the appropriate weighted factor equating to the resource needs. The constants then are the standards and weighting factor and the variables (workload data) are computed by ADP. A spin off benefit to the computer use would be : Programmed regression analysis; programmed correlation of current and historic data; and seasonally adjusted forecast workload requirements.

The final point, as I envisioned as our ultimate objective, is that reallocation of our human resources could be accomplished more accurately and more timely as shifts in workload occur from one geographic area to another and more responsive adjustments as workload increases or decreases.

If, in fact, there is any potential application of the "production contract attribute system" and if DCASR Boston is a microcosm of the DLA CAO macrocosm, then it would be even more appropriate to apply these concepts to the larger statistical community for more accurate analysis and conclusions.

I must emphasize that the current systems limitations exist merely to more accurately define workload and relate authorized manning to it. There is great deal more to the distribution of authorized positions to locations that is required such as; position management, position classification, organization structure and behavior which I have not addressed and which I do not mean to over simplify in this paper. There are some tasks which are not associated with contracts and consequently do not correlate to these characteristics. For example, industrial preparedness planning, industrial resources and perhaps pre-award surveys, cost/schedule control systems criteria programs, should cost and production readiness reviews. These efforts should be assessed from a program basis and data that is indigenous to those functions. Most of the resources are related to these dimensions and the regional staff should be treated as a percent to operations similar to an overhead cost of doing business. (The production directorate regional staff is 8.0% 29 to 362.) Clerical position requirements can normally be determined by a clerical to professional staffing pattern or ratio. Nothing of course takes the place of sound management judgment but justification for deviation due to anomalies should be ascertained.

As perhaps most research studies conclude, more research and analysis is needed to improve and refine the system.

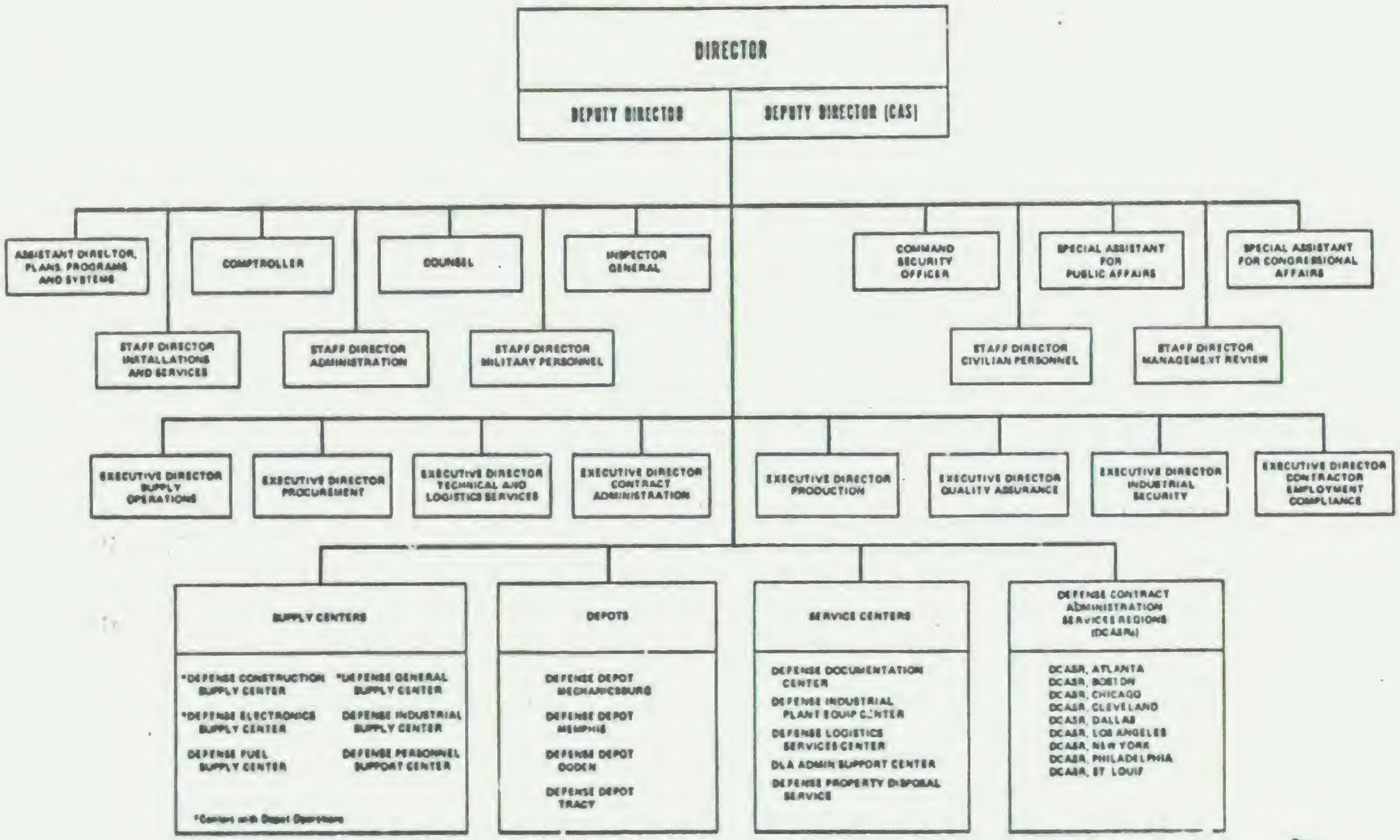
Finally unlike your newscast editorials, I assume total responsibility for the paper, the opinions, and conclusions.

SLIDE 1

- THE ORGANIZATIONAL RELATIONSHIP OF DLA AND DCASR BOSTON
- DCASR BOSTON'S ORGANIZATION AND ITS PRODUCTION ELEMENT
- MAJOR PRODUCTION FUNCTIONS PERFORMED
- WORKLOAD STATISTICS
  - REGION
  - PRODUCTION
- EXPERIENCES AND OBSERVATIONS OF WORKLOAD MEASUREMENT

SLIDE 2

DEFENSE LOGISTICS AGENCY

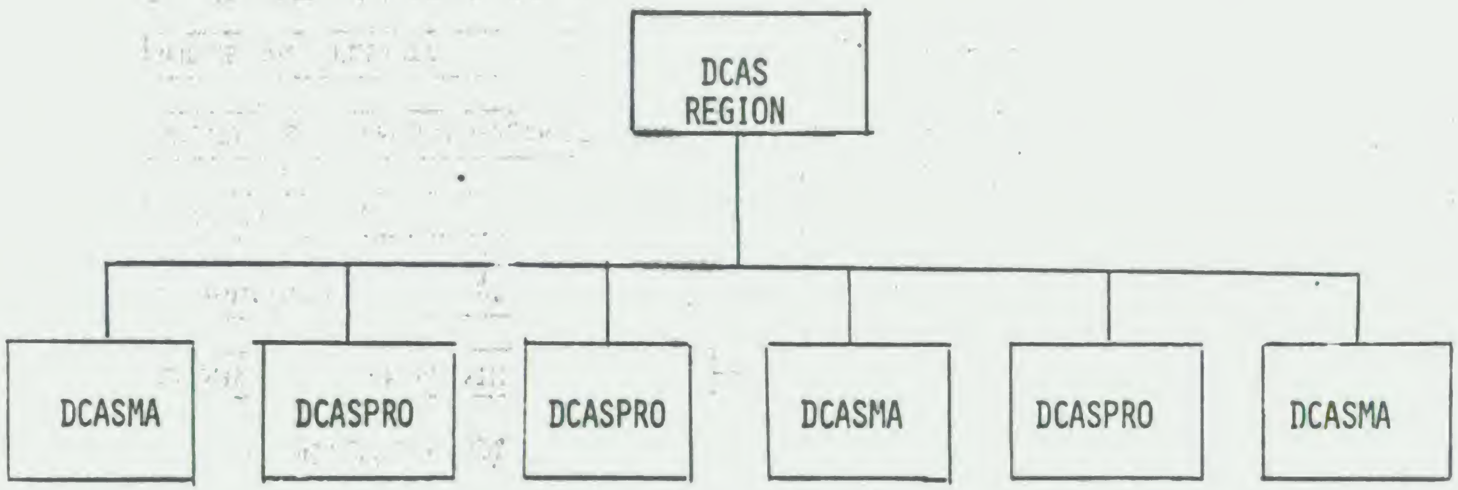


W. W. Vaughan

W. W. VAUGHAN
Lieutenant General, USA
Director

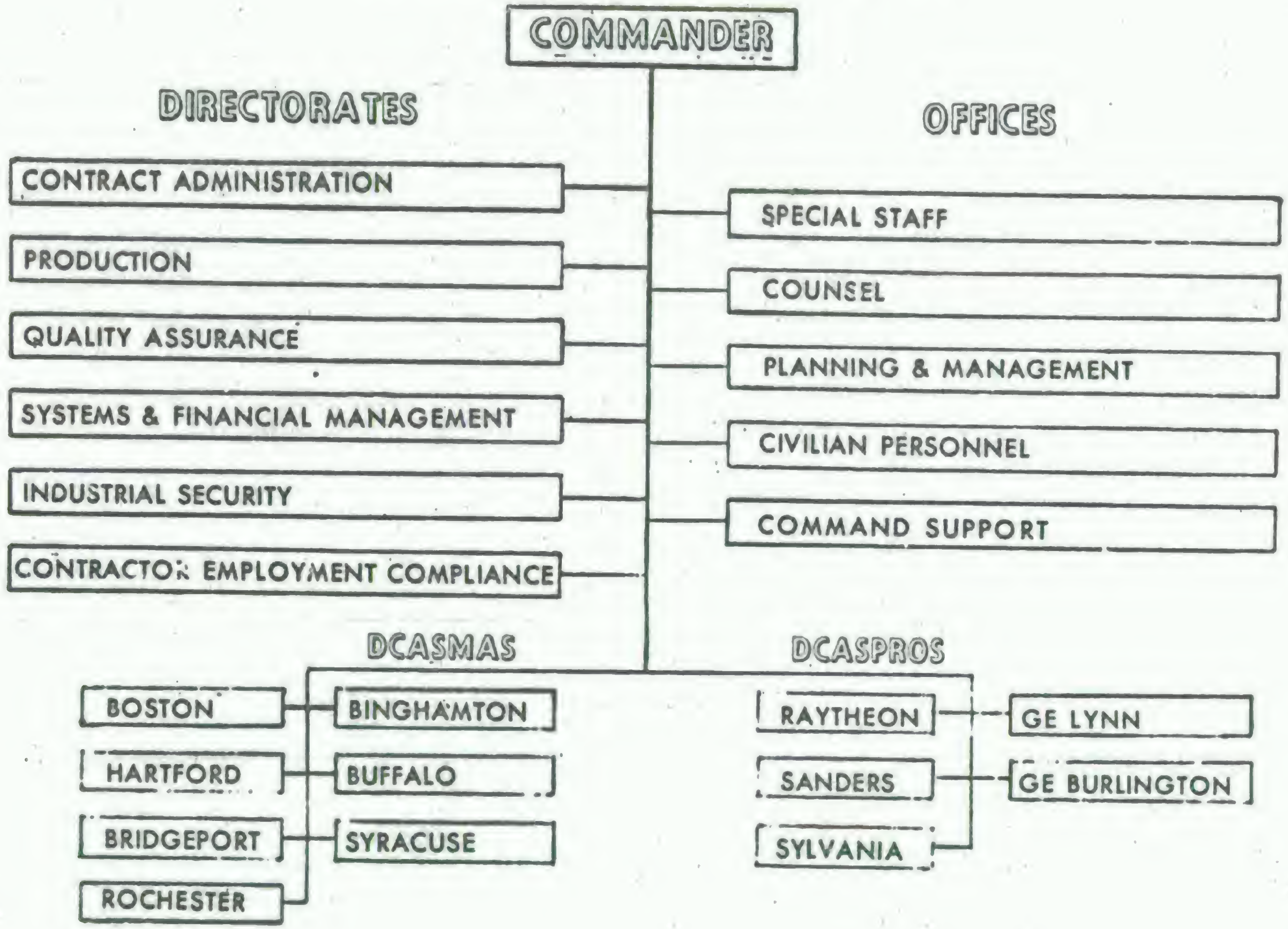
SLIDE 3

A TYPICAL DCAS REGION



ORGANIZATION STRUCTURE

SLIDE 4



SLIDE 5

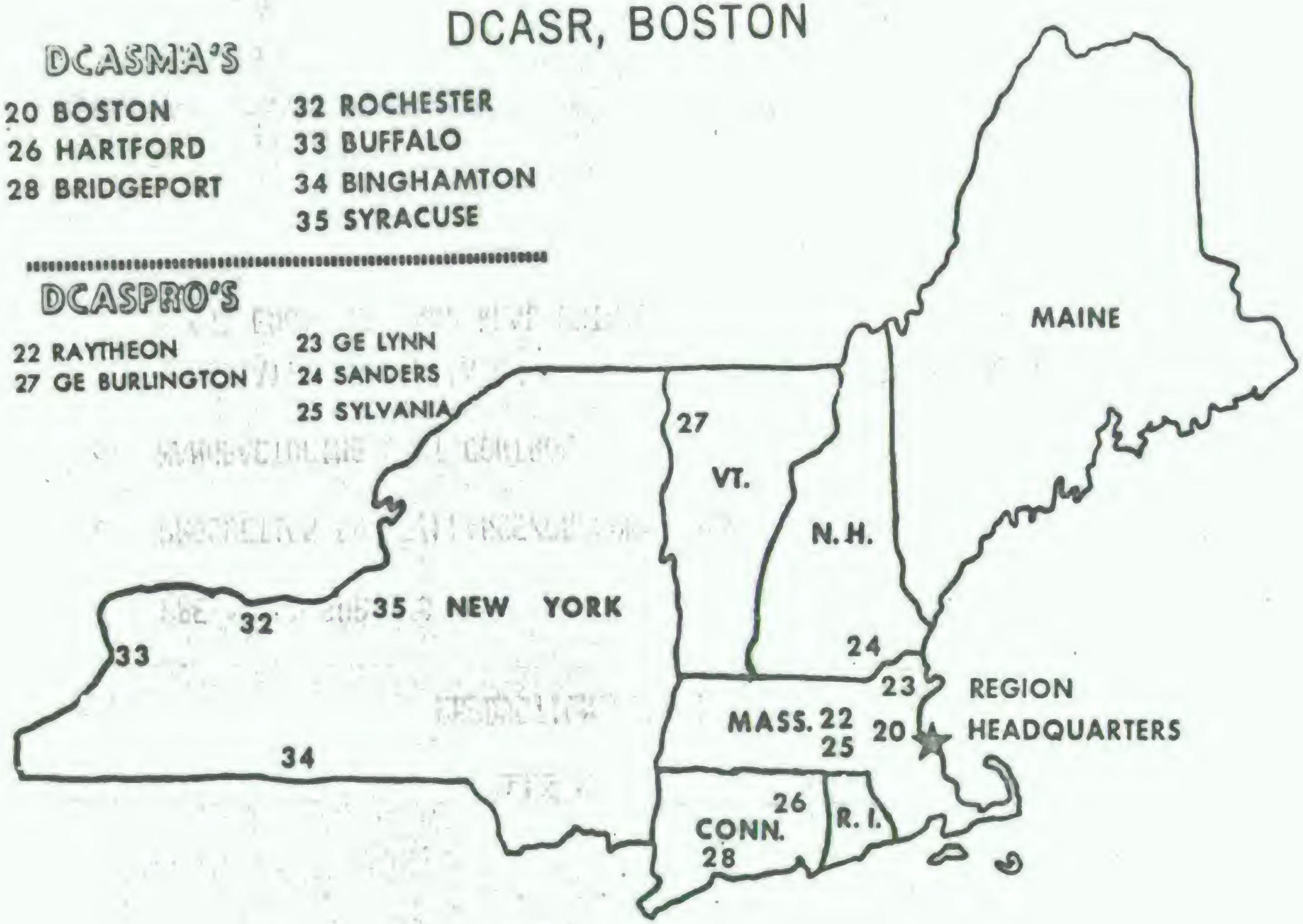
DCASR, BOSTON

DCASMA'S

20 BOSTON
26 HARTFORD
28 BRIDGEPORT
32 ROCHESTER
33 BUFFALO
34 BINGHAMTON
35 SYRACUSE

DCASPRO'S

22 RAYTHEON
27 GE BURLINGTON
23 GE LYNN
24 SANDERS
25 SYLVANIA



SLIDE 6

PRODUCTION FUNCTIONS

- PRE-AWARD SURVEYS
- PRODUCTION SURVEILLANCE/PROGRESS PAYMENT EVALUATION
- MANUFACTURING COST CONTROL
- UTILIZATION AND MAINTENANCE SURVEYS OF GOVERNMENT OWNED PLANT EQUIPMENT AND REAL ESTATE

SLIDE 7

PRODUCTION FUNCTIONS (CONTINUED)

- SURVEILLANCE OF GOVERNMENT OWNED PLANTS FOR COMPLIANCE WITH ENVIRONMENTAL PROTECTION AGENCY REGULATIONS
- SURVEYS FOR INDUSTRIAL PREPAREDNESS PLANNING REQUIREMENTS
- ENERGY CONSERVATION AND FUEL SHORTAGE ASSISTANCE
- ENGINEERING SURVEILLANCE AND ASSISTANCE

SLIDE 8

PRODUCTION FUNCTIONS (CONTINUED)

- EVALUATION OF PROPOSED ENGINEERING CHANGES
- VALUE ENGINEERING PROGRAM
- MANAGEMENT OF COST/SCHEDULE CONTROL SYSTEMS
- TECHNICAL SUPPORT OF SPECIAL EMPHASIS PROGRAMS
- TECHNICAL ANALYSIS OF COST PROPOSALS

SLIDE 9

PRODUCTION FUNCTIONS (CONTINUED)

- MONITORING OF ACTUAL AND POTENTIAL STRIKES
- COORDINATION OF REMOVAL OF CRITICAL DEFENSE MATERIAL FROM STRIKE BOUND PLANTS
- SERVICES RELATED TO THE ENFORCEMENT OF LABOR STANDARDS AND INDUSTRIAL MANPOWER REQUIREMENTS

SLIDE 10

PRODUCTION FUNCTIONS (CONTINUED)

- TIMELY SHIPMENT OF DAMAGE FREE MATERIAL VIA THE MOST ECONOMICAL MODE
- TECHNICAL TRANSPORTATION, TRAFFIC AND PACKAGING ASSISTANCE TO CONTRACTORS
- ISSUE AND CONTROL OF GOVERNMENT BILLS OF LADING

SLIDE 11

REGION STATISTICS

- CONTRACTORS 2,900 - 1,700 ACTIVE
- CONTRACTS 30,000
- FACE VALUE 12 BILLION DOLLARS
- UNLIQUIDATED VALUE 5 BILLION DOLLARS
- DAILY DISBURSEMENT 12.5 MILLION
- MANNING LEVEL 2,355

SLIDE 12

PRODUCTION DIRECTORATE STATISTICS

- CONTRACTORS - ACTIVE 1,500
- CONTRACTS 22,000
- FACE VALUE 9.7 BILLION DOLLARS
- UNLIQUIDATED VALUE 3.5 BILLION DOLLARS
- MANNING LEVEL 362

SLIDE 13

CONTRACT TURNOVER RATE METHOD NUMBER ONE

$$\frac{\text{CONTRACTS COMPLETED}}{\text{AVERAGE CONTRACTS ON HAND}} = \text{INDEX}$$

INDEX TIMES ACTUAL CONTRACTS ON HAND EQUALS CONTRACT EQUIVALENCY

$$\frac{25{,}000}{22{,}000} = 1.14$$

$$1.14 \times 24{,}000 = 27{,}360$$

SLIDE 14

CONTRACT TURNOVER RATE METHOD NUMBER ONE
REVERSE STATISTICS AND COMPARE DIFFERENCE

$$\frac{22,000}{25,000} = .88$$

88 X 24,000 = 21,120

$\triangle$ 27,360 - 21,120 - 6,240

$$\frac{6,240}{21,120} = 29.54\%$$

SLIDE 15

CONTRACT TURNOVER RATE METHOD NUMBER TWO

$$\frac{365}{344} = 1.06$$

1.06 X 24,000 = 25,440

REVERSE STATISTICS

$$\frac{365}{386.9} = .94$$

.94 X 24,000 = 22,560

25,440 - 22,560 = 2,880

$$\frac{2,880}{22,560} = 12.77\%$$

SLIDE 16

[illegible] April 197[illegible]

Directorate of Production
Summary of Major Workload Characteristics
and Authorized Operational Position Distribution

Location	Cat 1, 2 & 3 Contracts		Contract Turnover			Line Items		Sched Freq	SULO (Mil)		Active Accounts	
	No.	%	Rate	Equiv	%	No.	%	Sched Per L.I.	No.	%	No.	%
Boston	5460	25.24	1.69	9227.4	28.44	15,862	19.84	1.29	351	12.33	702	46.96
Hartford	5215	24.11	1.32	6883.8	21.22	13,202	16.52	1.19	233	8.18	365	24.41
Bridgeport	3027	13.99	1.78	3874.6	11.94	7,987	10.00	1.26	214	7.52	154	10.30
Syracuse	1544	7.14	1.45	2238.8	6.9	6,973	8.72	1.09	117	4.11	66	4.42
Rochester	455	2.10	2.95	1342.3	4.14	1,963	2.46	1.20	72	2.53	46	3.08
Buffalo	1079	4.99	2.18	2352.2	7.25	2,752	3.44	1.08	78	2.74	87	5.82
Binghamton	1729	7.99	1.48	2558.9	7.89	10,711	13.40	1.26	302	10.61	37	2.47
Raytheon	1344	6.22	1.37	1841.3	5.68	11,941	14.94	1.14	1040	36.53	20	1.34
G E Lynn	785	3.63	1.32	1036.2	3.19	1,888	2.36	1.51	111	3.97	7	0.47
Sylvania	130	.60	1.18	153.4	.47	1,950	2.44	1.40	69	2.42	6	0.40
[illegible]nders	410	1.9	1.51	619.1	1.91	2,840	3.55	1.19	100	3.51	4	0.27
E Burlington	452	2.1	0.85	384.2	1.18	1,865	2.33	1.98	158	5.55	1	0.06
Region Totals	[illegible]1630	100.0	[illegible]	32[illegible]4.5	100.2	79,934	100.0	1.34	2847	99.99	[illegible]	100.00
MAR	[illegible]1873	Trend ↑				76,[illegible]72	Trend ↓		2851	Trend ↓	[illegible]	Trend ↑
FEB	21481					80,427			2932		[illegible]	
JAN	21202					80,875			2943		[illegible]	

361

SLIDE 17
DIRECTORATE OF PRODUCTION
SUMMARY OF MAJOR WORKLOAD CHARACTERISTICS

30 April 1977

Location	% Contracts	% Contract Equivalency	% Line Items	Scheduled Frequency/L.I.	% $ULO (Mil)	% Active Accounts
Boston	25.24	28.44	19.84	1.29	12.33	46.96
Hartford	24.11	21.22	16.52	1.19	8.18	24.41
Bridgeport	13.99	11.94	10.00	1.26	7.52	10.30
Syracuse	7.14	6.9	8.72	1.09	4.11	4.42
Rochester	2.10	4.14	2.46	1.20	2.53	3.08
Buffalo	4.99	7.25	3.44	1.08	2.74	5.82
Binghamton	7.99	7.89	13.40	1.26	10.61	2.47
Raytheon	6.21	5.68	14.94	1.14	36.53	1.34
G E Lynn	3.63	3.19	2.36	1.51	3.97	0.47
Sylvania	.60	.47	2.44	1.40	2.42	0.40
Sanders	1.9	1.91	3.55	1.19	3.51	0.27
G E Burlington	2.1	1.18	2.33	1.98	5.55	0.06
REGION TOTALS	100.0	100.2	100.0	1.24	99.99	100.00

SLIDE 18

DIRECTORATE OF PRODUCTION

SUMMARY OF MAJOR WORKLOAD CHARACTERISTICS

30 APRIL 77

	CAT 1, 2 & 3 CONTRACTS		CONTRACT TURNOVER		
	NO.	%	RATE	EQUIV.	%
ROCHESTER	455	2.10	2.95	1342.3	4.14
GE BURLINGTON	452	2.10	0.85	384.2	1.18
RAYTHEON	1344	6.21	1.37	1841.3	5.68

	LINE ITEMS		$ULO (MIL)	
	NO.	%	NO.	%
ROCHESTER	1963	2.46	72	2.53
GE BURLINGTON	1865	2.33	158	5.55
RAYTHEON	11941	14.94	1040	36.53

SLIDE 19
DIRECTORATE OF PRODUCTION
SUMMARY OF MAJOR WORKLOAD CHARACTERISTICS
AND AUTHORIZED OPERATIONAL POSITION DISTRIBUTION

30 April 1977

	Contracts Dist.	Contract Equiv. Dist.	Line Item Dist.	Scheduled Frequency Dist.	ULO Dollar Dist.	Active Accts Dist.	Authorized Positions			
Locations	%	%	%		%	%	No.	%	Adjust For T&P	Actual
Boston	25.24	28.44	19.84	1.29	12.33	46.96	76	22.8	- 7	(83)
Hartford	24.11	21.22	16.52	1.19	8.18	24.41	65.5	19.67	- 1.5	(67)
Bridgeport	13.99	11.94	10.00	1.26	7.52	10.30	36	10.81	-	(36)
Syracuse	7.14	6.9	8.72	1.09	4.11	4.42	23	6.91	+ 2	(21)
Rochester	2.10	4.14	2.46	1.20	2.53	3.08	7	2.10	- 6	(13)
Buffalo	4.99	7.25	3.44	1.08	2.74	5.82	19	5.71	+ 2	(17)
Binghamton	7.99	7.89	13.40	1.26	10.61	2.47	24	7.21	+ 2	(22)
Raytheon	6.21	5.68	14.94	1.14	36.53	1.34	38.5	11.56	+ 2.5	(36)
G E Lynn	3.63	3.19	2.36	1.51	3.97	0.47	11.5	3.45	+ 1.5	(10)
Sylvania	.60	.47	2.44	1.40	2.42	0.40	11.5	3.45	+ 1.5	(10)
Sanders	1.9	1.91	3.55	1.19	3.51	0.27	11.5	3.45	+ 1.5	(10)
G.E. Burlington	2.1	1.18	2.33	1.98	5.55	0.06	9.5	2.95	+ 1.5	(8)
REGION TOTALS	100.0	100.2	100.0	1.24	99.99	100.00	333	99.97	-	333

AN AUTOMATED PROCUREMENT INSTRUMENT SYSTEM

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INTRODUCTION

This innovative system is the result of a task assigned within Department of Army Materiel Development and Readiness Command, DARCOM, to consider the application of word processing to achieve greater standardization of the procurement business.[1] As the inflation spiral quietly but surely erodes the operating budgets of both government and industry, sometimes overshadowing our efforts to obtain higher efficiency, the specter of ever dwindling resources prompts us to explore even more efficient and economical methods of accomplishing our mission. Such was the case in the early months of calendar year 1975 - the problem of administrative costs of procurement. Initially, Automatic Data Processing (ADP) was reputed to be the manager's solution to reduced manpower. In actuality, ADP was supplanted for manual record keeping as an "after-the-fact" application of procurement awards. In no instance was ADP providing a totally mechanized award except for the Defense Logistics Agency (DLA) program on small purchases. The DLA program provides total automation but is restricted to procurement buys that are for cataloged priced items under $10,000. The DD Form 1155 and Standard Form 36 are utilized to reflect the data and applicable provisions and acceptance required by the preprinted DD 1155-R. The computer operated system records the data and produces management reports. However, the restriction to $10,000 could not be overcome without complete redesign and programming effort to accomplish the requirement to automatically produce all instruments regardless of dollar value. Rather than adopt this system as the answer to small purchases, we determined to pursue a development that would encompass all instruments within a systems approach, rather than interconnect various sub-systems. Some semi-automated programs currently produce data, but in no case provide the ASPR clauses and references. This portion of the procurement instrument was being produced by attaching "boilerplate" pages of clauses and narratives. Word Processing - the application of systems analysis and electronic technology in production of typed words - is a conceptual cousin of ADP. The use of sophisticated mechanization provides more typed material with the same labor input. Word processing provides a dependable supply of typing assistance to management and affords a new career path in learning new techniques and developing new skills to the typist.[2]

In early 1975 a review of word processing as applied to procurement operations was made on how procurement assignments had been optimized. In one instance, a word processing center had been established as a dedicated group, responsible for processing and capturing contractual data. Standard clauses and other pertinent, repetitive contract data were placed on magnetic cards and systematically inserted into solicitations or contracts at the time of their preparation. The advantages were increased productivity, monetary savings, and efficiency as well as standardization of the procurement applications. At this time the task became a joint effort with Directorate, Management Information Systems, to capitalize on word processing systems, particularly in the contracting aspects of the Commodity Command Standard System (CCSS). Some of the questions to be answered were:

1. Are we using word processing techniques and equipment in preparation of solicitations and contractual awards?

2. Can we do more?

3. Do we have a standard system?

4. Have instructions in this area been disseminated?

5. Can we further automate purchasing and contracting functions by the use of mini-computer with integrated word processing equipment?

Consideration was given to take full advantage of the data already in the Commodity Command Standard System (CCSS) computers as well as the automatic update of contractual data to the CCSS data base.[3]

Decisive action was taken in May 1975 by the Army to examine the problem at its very roots - the word processing workload in the procurement area.[4] A Task Force was developed at the Army Missile Materiel Readiness Command comprised of personnel with experience and expertise in Automatic Data Processing and Functional Procurement. The command was given the functional responsibility for system design in October 1975. Controls were identified as follows:[5]

1. The mini-computer would be installed in the procurement area.

2. The Directorate for Management Information Systems would have control, maintenance, and operation of the mini with terminal operators to be provided by procurement.

Initially assigned projects to be developed and programmed encompassed:

1. Solicitations for firm-fixed price hardware over $10,000.

2. Small Purchase system to incorporate the quotation feature.

3. Automatic update to the Materiel Acquisition and Delivery (MAD) File (data base recording purchase requirement data) and Military Standard Contract Administration Procedures (MILSCAP) Master File of the standard system.

Also included as possible follow-on requirements were:

1. Modifications for the above.

2. DD 350 preparation.

3. No-cost modifications posted to the MILSCAP Master File (MMF) of the CCSS.

Rationale and circumstances which determined the extent and application to be incorporated into the automated system were the first consideration of a System Concept Document. It was recognized that a totally automated contractual instrument preparation, utilizing source data from existing CCSS records, had not been encompassed in the CCSS. Therefore, the entire requirements for automation within the Procurement and Production area had not been satisfied by the initial standard applications. It was recognized, from the inception of CCSS, that follow-on design and programming would be required to complete the functional processing requirements in the procurement area.

Our initial analysis revealed that the word processors currently in use were not capable of satisfying the needs of the procurement function when applied to the total word processing workload. Equally evident was the fact that limiting the scope of the system to only those assigned objectives would not fully utilize the capabilities of a mini-computer. It was determined that the practical approach would be to design the system in line with the current state - of-the-art for mini-computers, fully utilizing their capabilities. This, in effect, would optimize benefits from the investment. Currently, word processors used in the procurement area are of two types, both originating from a typewriter. The first type is a key board that creates an extract tape or card in the exact format as the typed document. The second type is a key board that requires the procurement forms to be blocked in exact character length in order to permit the optical reading of the typed document. In some cases it is possible to create cards or tapes containing the ASPR clauses and references in lieu of resorting to "boilerplate" pages.

It must be remembered that for a procurement instrument to be individually "tailored", a typist must control the paragraphs by manual intervention as each document is being prepared. Even though the advantages of increased productivity, monetary savings, and efficiency as well as standardization can be accomplished by word processing, the then present method of accomplishment was not the ulitimate. The decision was made to utilize the mini-computer as a high level of word processors to produce all outputs. Attendant with the mini will be terminals consisting of a key board and cathode-ray tube for data entry. Other equipment determined as a requirement for the system are:

1. A Text Processor to align the printed words and format, as necessary, based on additions, changes, and deletions to previously stored data.

2. Discs and tapes to store accessable data.

3. A high speed printer to be attached to the mini-computer to produce the contract instruments for manual review and concurrence prior to printing the total quantity for distribution.

4. A communications link connecting the procurement location with the printing facility to preclude manual distribution of documents for reproduction.

Even though the word processor typewriters would not be used for input by the procurement personnel, they could interface other functional areas, as in the creation of the detailed scope of work and DD Form 1423 to be attached to the outputs of the mini-computer to encompass the total procurement package for solicitation or award. The completed systems concept document was formulated to encompass all procurement outputs to be generated from a mini-computer utilizing terminal input in a direct access - real time processing environment.

The system concept was developed to produce the following automated outputs:

1. All solicitation instruments regardless of dollar value and contract type.

2. Amendments to solicitations.

3. Award instruments for automated and non-automated solicitations.

4. Contract modification instruments.

5. DD 350 and related documentation preparation.

6. Selected matrices and tables.

7. Simultaneous update to Materiel Acquisition and Delivery (MAD) and MILSCAP Master Files of CCSS.

The development and implementation of the PADD System will provide for:

1. Control and management within the Procurement and Production area of the data generated as a result of solicitations, contractual awards, and modifications thereto.

2. Responsive support to the procurement area which will in turn provide better visibility to other functional areas, e.g., logistics, research and development, and financial.

3. Standardization of contract preparation and data alignment on the prescribed contractual forms.

4. Assurance that the documents prepared and the data generated therefrom for CCSS update are complete, compatible and valid prior to signing the award.

5. Better utilization of resources manpower in overall procurement assigned missions.

6. Capability to provide current data, in a more timely manner, for management reports.

7. Elimination of costs associated with keypunching card input required by the current CCSS system.

8. Ability to reduce paper required for contractual preparation as a result of tailoring ASPR requirements

9. Capability, via computer programming and storage, of providing instant updating under controlled conditions at terminal locations, all codes, tables, matrices, remarks, and ASPR clauses.

10. Reduction of data elements required to be entered manually at time of solicitation, award, and modification therefor by utilizing existing data previously recorded in CCSS and the automated procurement instrument mechanized files.

SCOPE AND PURPOSE

The name of Procurement Automated Data and Document System (PADDS) was assigned to cover the following modules or processes:

1. Solicitation Instrument - Automated Process.

2. Contract Instrument - Automated Process.

3. Modification Instrument - Automated Process.

4. Reject and Suspense Process.

5. Management Requirement Process.

The basic functions to be performed by the proposed systems are:

1. Solicitation Instrument - Automated Process:

a. Basic

The initial action required in the process of creating an automated solicitation is usally the selection of prospective offerors.

The Standard Automated Bidders List (SABL) has been developed to provide this data to the Contract Specialist. SABL is not an integral part of PADDS but is accessible via PADDS terminals. When SABL is to be utilized in the procurement action, the solicitation process is initiated by accessing SABL for a list of prospective offerors.

Simultaneous with the access of SABL, PADDS will assign and reserve a solicitation number for the action being processed.

When the presolicitation actions have been completed, the Contract Specialist can resume processing the solicitation, citing the reserved number, in order to key all actions to the appropriate number.

The decision making process is performed by the Contract Specialist prior to the resumption of processing the solicitation. A brief transcript reflecting those decisions, plus the selection of appropriate codes, is furnished to the terminal operator for entry.

Data is arranged and entered in the segments, with edit and validation occurring at the conclusion of each segment. Validation is performed against the CCSS data base and PADDS. In the event data is invalid, an in-the-clear error message will be displayed on the terminal screen for immediate correction.

When all data have been entered and validated the Contract Specialist will be furnished a hardcopy of the solicitation for purposes of obtaining required reviews and approvals. When all concurrences have been obtained and the Contract Specialist desires to issue the solicitation, an electronic message is transmitted to the bulk printing plant requesting the appropriate number of copies and mailing labels. This is accomplished via a communications link between the procurement area and Field Printing Plant over which PADDS data is transmitted and captured on disc for reproduction. This feature eliminates the need for hardcopy transmittal between these two processing points.

b. Amendment

Should it become necessary to issue an amendment to an automated solicitation the Contract Specialist may do so by accessing the PADDS Solicitation File, keying the action to the appropriate solicitation number. It will not be necessary to reenter data that is pertinent to the amendment, since it is on record in the solicitation file. The only data to be entered is that which is being changed or that which is being added or deleted. The amendment number will be computer assigned.

Hardcopy processing will be accomplished in the same manner as the basic solicitation.

2. Contract Instrument - Automated Process:

a. Award Based Upon Automated Solicitation

Generation of a contract instrument to make an award resulting from an automated solicitation is a very abbreviated process. The PADDS Solicitation File will be accessed to obtain the majority of the data required for generating the award document after which it is necessary to enter only the data that has resulted from negotiations, in the case of negotiated procurement, or the evaluation process, if formally advertised.

Edit and validation is applied to the generation of the contract instrument in much the same manner as in the solicitation process, being performed in segments, with error messages advising the terminal operator if invalid data is entered. Corrections are made and data are revalidated at the terminal. Although PADDS is not designated to process funding documents, it will effect an interface with CCSS files, at the time award is contemplated, for the purpose of notifying the Contract Specialist in the event sufficient funds are not available to execute the contract.

Following completion of the entry and validation of data elements the mini-computer will furnish a hardcopy for the purpose of obtaining reviews and approvals. Accompanying the contractual instrument will be the automated DD 350, "Individual Procurement Action Report" if required. All data associated with the contemplated award will be retained in the PADDS Suspense File pending execution of the contract.

b. Awards Based Upon Non-Automated Solicitations

PADDS includes the process for generating a contractual document by automation when award results from a non-automated solicitation, including the unsolicited proposal. In this instance, there are no pertinent data in the PADDS Solicitation File. Consequently, the majority of data elements that would have been entered during the solicitation process must be introduced at this time to produce the contract instrument. In addition thereto, other data elements associated with the award process must be inserted. A first impression is that additional effort is required to make an award when the solicitation was non-automated; however, under closer scrutiny it becomes evident that the above assumption is not true. What really occurs is that the entry of data elements of both phases are combined in one operation.

Edit and validation are performed as in the previously explained processes and a hardcopy of the contract instrument and accompanying DD 350 are furnished to the Contract Specialist. All data associated with the proposed award are suspended in the PADDS Suspense File pending execution of the contract.

c. Updating Data Bases

Capturing and processing data resulting from awards for the purpose of establishing and maintaining a data base of procurement information, have long been voluminous, costly, time-consuming tasks. Whether the method be manual or automated, the consequences

remain basically unchanged. PADDS provides update of both the CCSS and inherent data bases. Little or no additional effort is expended in accomplishing the update function due to the basic concept of PADDS, more specifically defined as source data and document automation. The underlying principle of Source Document Automation is the practice of coding selected portions of the data appearing in procurement instruments in order to capture that data without further effort. This represents a substantial advancement over manual abstracting and optical character recognition or magnetic card or tape methods.

Release of the captured data to the CCSS data base updating process is triggered by the insertion of the Effective Date of Award. This action also serves to update PADDS files in which award information is stored.

3. Contract Modifications - Automated Process:

The task of producing a contract modification has been greatly simplified by PADDS. The system accesses the PADDS and CCSS files to retrieve data accumulated from the award process. To acquire data from any other portion of the contract the Contract Specialist need only enter the contract number and advise the system of action contemplated. Data elements such as contractor name, address, all codes and other "header data" are retrieved and printed without further effort on the part of the Contract Specialist. The modification number is assigned by the mini-computer in numerical sequence.

Provisions have been made within the system to accomodate the entry of narrative at the terminal. This makes it possible for the Contract Specialist to tailor the language of the modification to the exact terms desired. This feature is also applicable to all phases of the automated process.

When all data have been entered and validated, a hardcopy is produced within the functional procurement area in order that reviews and approvals may be obtained. PADDS Suspense File holds the action pending execution. Even though modifications are produced in numerical sequence, PADDS will accept the notification of execution of modifications that are out of sequential order.

The process that updates the data bases and produces appropriate reports resulting from contract modifications is identical to that for basic contract awards.

4. Reject and Suspense Process:

Maximum edit and validation will occur at the time the data is entered at the terminal. In-the-clear error messages appearing on the terminal screen will tend to reduce rejections to a minimum. There are, however, some instances where final validation cannot be effected at the terminal. The Reject and Suspense Process provides the means of notifying the user of invalid entries discovered in final validation, and, in addition, thereto, provides for retention of the input pending correction of the data. When the errors are corrected processing will continue.

If the user desires to interrupt processing of a procurement instrument for reasons such as notification by the requiring element that changes to the requirement are contemplated, PADDS will retain the partially completed action in the Reject and Suspense File for seven working days, allowing resumption of the process within that period of time without loss of input.

Solicitations, Awards, and other procurement instruments that have been suspended in the file pending issuance or execution will be retained until disposition instructions are entered. Reports of suspended actions will be produced upon request for the purpose of informing management of their status.

5. Management Requirements - Management and Requirment Process:

The data base that will be established as a result of the foregoing processes will constitute a valuable source of information from which managment may format for reporting purposes. The Reject and Suspense File contains information pertinent to unawarded actions. The data accumulated as a result of awards are pertinent to reporting against total mission accomplishment. Incidental to these factors, status reports of individual actions may be extracted from PADDS files.

Reports required to be made on individual actions have been explained within their respective processes. The contract distribution list and mailing labels are other functional type by-products of PADDS that are associated with the processing of individual actions.

Registers listing solicitations, awards, DD 350 reports, and a list of procurement actions that were determined to be exempt from pre-solicitation synopsis in the Commerce Business Daily are examples of by-products of data accumulation in PADDS. The full extent of reporting requirements cannot be accurately determined due to the ever changing circumstances facing the procurement world. Offsetting this uncertainty, however, is the capability with this system to retrieve, by random access, any data contained therein. This method does not require special coding or special programming to render the stored data accessible. The nature of the system, i.e., composition of documents utilizing coded "building modules", complements the random access feature of the minicomputer. It is anticipated that the combination of these factors will produce above the average capability to respond to the multifaceted reporting needs of the procurement area.

DISCUSSION OF DETAILED FUNCTIONAL SYSTEMS REQUIREMENT

Identification of data elements relative to all outputs was made and the elements were compiled into categories.[7] The first category contained elements that were available in the CCSS data base, (MAD File), as a result of a valid procurement requirement. Subsequent categories defined the elements required for solicitation and award, MILSCAP codes and components, data for the DD 350, distribution list, and other readily identified management reports. Data elements identified by two or more names were equated for systems design and programming.

Once the data elements were identified, format of the outputs was the next consideration. A comparison of the data elements contained on the Standard Form 36, Continuation Sheet, currently produced by the Command's semi-automated contract instrument system was made. Requirments of ASPR 2-201(a) and 3-501(b)(3) were also reviewed. As a result, the determination to consolidate all data elements required by the ASPR Uniform Contract Format Sections B, C, D, E, and F was made. This application aligns the supplies/services and prices; description/specifications; preservation/packaging/packing; inspection and acceptance; and deliveries and performance data into an "entity" of data to be contained under the assigned Contract Line Item Number (CLIN) identification on the solicitation and award outputs. This provides the viewer a full picture of the requirement, stated in one location, rather than review of five sections to ascertain the total essentials. Special consideration was given to the reduction of pages saved on competitive awards due to the austere restrictions placed on paper acquisition and useage. The decision to rearrange the sections of the Uniform Contract Format (UCF), required an ASPR deviation for authority.[8] The deviation, which affects both the Table of Contents and Uniform Contract Format, and pertains to both formal and negotiated procurements will:

1. Realign all the elements required by the Uniform Contract Format in such a manner that will alleviate the problems encountered in current efforts to generate a contractual document containing only the data pertinent to the awarded instrument by merely removing the pre-award data pages in a random manner. The current method requires restatement in the "List of Documents" (Section M) as to the pages that have been withdrawn and/or renumbered, causing considerable confusion and often raising doubts as to what actually constitutes the intended document.

2. Separate pre-award data, e.g., representations, certifications, and other statements of the offeror; solicitation instructions, conditions, and notices to offeror; and evaluation factors for award. This information would no longer be co-mingled with data required for post award functional applications (administration, production management, inspection, acceptance, payment, closeout, and retirement).

3. Result in an ancillary cost savings from the realignment as the pages required for pre-award data would not have to be reproduced and perpetuated in the awarded instrument. In some forms of contracting this reduction constitutes as much as 45% savings in the number of printed pages required.

Statistics compiled for a DoD wide application are summarized in support of the cost savings:

	CURRENT PROCEDURE COMPETITIVE SOLICITATION & AWARD	PROPOSED PROCEDURE COMPETITIVE REARRANGED UNIFORM CONTRACT FORMAT
Total Pages Printed	5,443	3,830
No. of Pages Saved Per Award		(1,613)
Total No. Saved Per DoD Awards of 39,436 Per Annum		63,610,268

	CURRENT PROCEDURE NONCOMPETITIVE SOLICITATION & AWARD	PROPOSED PROCEDURE NONCOMPETITIVE REARRANGED UNIFORM CONTRACT FORMAT
Total Pages Printed	1,222	532
No. of Pages Saved Per Award		(690)
Total Number Saved Per DoD Awards of 59,056 Per Annum		40,748,640

SUMMARY OF COMPETITIVE AND NONCOMPETITIVE SAVINGS

104,358,908

In addition to the paper savings, collateral costs per printed page could be determined by each agency. Converting the savings to a minimum monetary value at one penny per page, the estimated amount exceeds one million dollars annually plus attendant costs of postage.

4. Consolidate Table of Contents, Part I, Sections B through F (proposed deviation), e.g., supplies/services and prices; description/specifications; preservations/packaging/packing; inspection and acceptance; and deliveries and performance data under the Contract Line Item Number (CLIN) on the SF 36 Continuation Sheet. However, it must be recognized that additional sheets containing special explanatory provisions for inspection and acceptance and/or deliveries and performance may be required and these provisions have been encompassed in the deviation.

5. Benefit all parties concerned with a post award document, in reading data pertinent to a particular Contract Line Item Number (CLIN), without the usual search through numerous pages in order to locate administrative data relative to any specific CLIN.

The benefits, as described above, are of a stand-alone nature. However, when coupled with the mini-computer application, other benefits are to be realized. Some of these are:

1. The incidence of errors in manual preparation would be greatly reduced by automation as a result of extracting pre-validated data from the mainframe computer and by recall of stored data in the mini-computer.

2. The instantaneous display of data input prior to creating the contractual document. This fact, in itself, will reduce administrative modifications.

Coupled with the decision to realign the Table of Contents and Uniform Contract Format was the determination to let the mini-computer "free-form" the data to be printed on the SF 36. The mini will print headings above the variable data thus allowing for fluctuating narrative and instructions to be printed for each line item. This will also provide the capability for continuous printing without changing forms. The forms comparable to the SF 26, SF 30, and SF 33, granted under the deviation for conducting a Source Data Automation (SDA) test for word processing (typewriter or optical character reader), were reviewed. Even though the PADDS documents will be computer generated and not require specified data element limitations, it was decided to utilize the SDA forms for the cover or front page of the contract instruments for the sake of standardization.

In addition to providing for the complete procurement business under the automated PADD System, a number of innovative management tools were also developed.

The Regulation Reference Record was developed to store all references/clauses/narratives required by ASPR, Army, DARCOM, and local Major Subordinate Command (MSC) to be produced on the contractual instruments by the computer. A six position element code was appended to each clause/reference in the file, and by the entry of this code, the complete title, date, and narrative is able to be generated. The first digit of the element code identifies the section of the ASPR Uniform Contract Format in which the item appears if the UCF is applicable. The second digit identifies the authority or regulatory requirement:

A - Armed Services Procurement Regulation (ASPR)

D - Department Regulation (Army)

M - Major Command Regulation (DARCOM)

S - Major Subordinate Command Regulation (MIRCOM)

I - Commodity Command Standard System (CCSS) data element

The third position identifies whether the clause is to be stated as full text or by reference only. The final three digits are numeric, commencing with 001 for each section of the UCF and generally will be in numerical sequence throughout each section. To preclude duplicate items from having to be loaded to the record, as for data elements appearing on automated solicitations and awards utilizing the DD Form 1155, the first two positions are coded "Ø5" to identify that sections of the UCF are not applicable. When used in automated small purchases, article numbers will be assigned to the elements as they print out on the instrument. Based on the dollar value, type of solicitation/award code, type of line item being procured, and special cost code the computer will automatically extract the required standard regulation references applicable to the specific award. Ability to add, change, or delete individual references is provided on an "as required" basis by the use of the element code described above. Such changes will not alter the data base but will allow for "tailoring" individual requirements. An errata sheet will be produced with each contractual instrument and where changes have been made to the standard narrative, will identify the specific data element and page number on which the change is printed. Where no deviations occur the notation, "No deviations/changes are included in solicitation/contract number ________________" will be printed. This application will optimize the manual review, and upon completion of required review will be filed in the pre-award portion of the procurement package. The properly annotated errata sheet will be maintained to show that each reviewing office having cognizance over the contents of the contractual instrument had knowledge of the changes. The production of only applicable clauses, and references will alleviate the current practice of "boilerplating" and then stamping "Delete" over the references that are not applicable to the individual solicitation/award. This record, as well as the other matrices may be updated at the terminal, but will be under a controlled environment to assure compliance and correctness of data.

The Weapon System Matrix was developed to automatically produce the Army system or equipment code required for DD 350 preparation. The matrix is controlled by the Weapon System Code and cross-references to provide the Army Budget Activity Code (Command Management Structure Code); Federal Supply Class (FSC) or Service Code; System or Equipment Code; and the Description of Commodity or Service. The matrix will produce the In-the-Clear data as well as the codes on the Individual Procurement Action Report. The description for supplies and equipment will be computer generated from the command management structure code contained in the MAD File. As in the other matrices, an override capability exists in this matrix also, to further define the description when warranted.

The Buyer Identification Matrix contains the two-position code assigned to each Contract Specialist within the command. The entry of the Buyer Code retrieves: Buyer Name, including title, first and last name, Attention Symbol of the Buyer's Procurement Office; Telephone Extension, including Area Code, Commercial and AUTOVON Number; Depository Location, Room and Building Location where Buyer resides; Command Identity and Geographical Location/City, State and Zip Code. This matrix will be the responsibility of each command, with update via terminal entry.

The Contract Payment Notice Recipient Matrix is a cross-reference from the Fiscal Station Number in the accounting classification to the applicable DoDAAD Code for the Contract Payment Notice Recipient. This matrix will produce the code required for MILSCAP. As with the Regulation Reference Record, this matrix is controlled by a central point within the command to assure updating on a current basis as well as control over the data.

The Contractor Identification Header Matrix which is controlled by the Contractor Identity Code from the H-8 handbook, is the most complex of all matrices. The Contractor Identification code will generate the codes and addresses for the Contract Administration Office (CAO), Contract Administration ADP Point, and Paying Office as well as the address of the contractor. Where a Contractor Facility Code is applicable, this entry will generate the applicable codes for the DD 350 preparation. If a facility is non-applicable, the DD 350 codes will be generated from the Contractor Identification Code. The matrix will produce all of the codes and related addresses for contracts, modifications, and DD 350 outputs and will print the applicable data in the prescribed blocks on the forms. Changes, additions, and deletions are entered from the terminal to update the matrix. This matrix is also controlled by a central point within the command to assure that all changes are incorporated on a timely basis. Overlay technique, via terminal entry, is provided to enter local command codes when an award is retained by the command for administration and payment.

The contractor's zip code is recorded in a separate identifiable location in the record to facilitate inquiries required for GAO and congressional requests. This matrix, alone, will reduce research time and provide accurate and complete data to be generated on the output, thus reducing administrative modifications to correct the required codes and addresses. The matrix will be manually built by our command to meet the prototype testing. However, action is being initiated by headquarters to acquire a tape update. This quarterly update tape will be converted to update the matrix automatically. Prior to this, update will be accomplished by terminal input.

Other management improvements, not within the matrices development are:

1. The Dollar Threshold is an optional code which may be entered when there is reason to believe that the anticipated differences of all combined Procurement/Work Directives (P/WD's) is within 25% of the actual P/WD totals. This entry will "override" and request the required clauses and narratives for the next higher level threshold to be generated. Seven ranges, from $2,500 or less to over $1,000,000 are identified.

2. The Contract Line Item Number Identity Code defines the CLIN requirement and recalls the appropriate clause definitions. CLINs are identified for the following requirements:

a. Production Quantity.

b. First Article Quantity.

c. Production Quantity Without First Article.

d. Option Quantity.

e. Multi-Year Program Quantity.

f. Service Line Item.

g. Data Item - DD 250 not required.

h. Data Item - DD 250 required.

i. Prototype (Shop-Queen) Item.

j. Maintenance and Overhall (Rebuild) Item.

3. The assignment of codes to delivery schedule data has optimized the changing or revising of dates, consignees, and MILSTRIP's under PADDS processing. Instead of entering the existing data elements requiring modification, a Document Number Relationship Code and Delivery Schedule Relationship Code were developed to specifically identify the line or lines to be updated. The use of these codes precludes the entry of approximately thirty characters to specifically distinguish which MILSTRIP line is affected. When an item is required to be diverted from one consignee to another or schedule delivery date is revised, only the relationship codes and changed data need be entered to effect the modification and generation of MILSCAP abstract transactions.

4. Awards which contain options may cite a range quantity applicable to the exercise of an option. In these cases, a firm Purchase Unit Price may be stated or a not-to-exceed Purchase Unit Price may be stated. The option CLIN will be stated as awarded with the Purchase Unit Price also stated but no quantity and no extension to Total CLIN Amount. Awards which cite single quantity options, will state quantity, Purchase Unit Price, and Total CLIN Amount. However, this amount will not be included in the Total Amount of Contract until the option is exercised, even though the CLIN amount is stated on the hardcopy instrument. Data required to be printed on the contract or contract modification for option CLIN's are determined by entry of the Procurement Request Order Number (PRON) for the initial awarded identical item. This entry extracts the NSN, FSCM, Long Manufacturer's Part Number, and Noun from the file. When an option is exercised, a PRON/PRON Amendment will be generated to furnish funding and additional data elements.

5. Awards which contain incremental funding are awarded for an amount greater than initially funded. The total agreed upon contract amount will be stated on the hardcopy instruments as well as the total obligated amount by accounting classification (ACRN) and the Total CLIN Amount will be the summation of the cost of all phases of performance included under that CLIN. In the case of multiple CLIN's, the same applies. In such instances, the sum of all CLIN's will equal the Total Amount of Contract. However, for MILSCAP purposes, the obligated and Total CLIN Amounts will only be for the initially funded dollars.

6. Awards which contain multiyear requirements are awarded for the total of all program years. This total agreed upon contract amount will be stated on the hardcopy instrument. Initially, only the first program year will be funded with provisions for notification to the contractor, on or before a specific date or event, as to whether the succeeding program year will be funded. This procedure continues throughout the contract. In the event that subsequent program years are cancelled, the contract will contain the formula and a limitation by which cancellation costs will be computed. The hardcopy instrument will contain the quantity, Purchase Unit Price, and Total CLIN Amount identified to a specific CLIN for first, second, and subsequent years. Options, under multi-year requirements will be stated as defined in paragraph 4. above. Data required to be printed on the contract or contract modification for subsequent multi-year requirements is determined by the entry of the PRON for the initial awarded identical item. This entry extracts the NSN, FSCM, Long Manufacturer's Part Number, and Noun from the file. However, for MILSCAP purposes only those CLIN's which are awarded and funded for the first program year will generate MILSCAP CLIN transactions on the basic contract instrument.

The above option, incremental funding, and multi-year applications require that the Total Amount of Contract be a manual entry in lieu of the computer generation of Total Amount of Contract from the summation of all the Total CLIN Amounts. The CLIN's assigned for options and multi-year requirements will be retained on the Contract File of PADDS for future application.

7. A Delivery Order Header Record is available within the system to benefit the Contract Specialist in processing orders under Delivery Type and Basic Ordering Agreement awards. Standard data elements applicable to the basic agreement are stored for automatic retrieval. Only the basic agreement number need be entered and the system will automatically assign the next sequential order number to the unobligated requirement. As with other requirements, the PRON is the interface to generate the data applicable to the CLIN or CLIN's. Therefore, this application provides for almost total computer generation of the data required for each order.

Extensive logic charts were developed for each data element by individual application. Application, input or output, or computer generation was identified; interrelationship with associated elements was documented; and the data element was explained. The associated Regulation Reference Code was appended for complete visability in programming.

CONCLUSIONS

The system design and development have been considered from the systems approach. It has become accepted that complex systems cannot be produced by merely inter-connecting component sub-systems. Any operating entity must be designed from an overall view if full integration and maximum effectiveness are to be achieved. The use of the systems approach was a determing factor in incorporating all procurement applications in the PADD System.[10]

Based on the systems approach, as well as the other unprecedented applications, the provisions and benefits of the PADD System are stated below:

1. Utilize source data and source document applications to record data at source of entry to improve the validity and timeliness of management reports and allow the contracting officer to have precise control over data generated from contractual instruments.

2. Reduction of data elements required to be entered manually at time of solicitation, award, and amendment, or modification thereto, by utilizing source data previously recorded in CCSS and PADDS files.

3. Utilize ASPR clauses, by reference and In-the-Clear, and standard statements in the generation of the contractual documents.

4. Assure that the documents prepared and the data generated therefrom for CCSS update are complete, compatible, and valid prior to signing the award.

5. Standardization of contract preparation and data alignment on the prescribed contractual forms.

6. Capability to provide current data for management reports in a timely manner, thus providing better utilization of manpower and better visibility to other functional areas, i.e., logistics, research and development, and financial.

7. Capability, via computer programming and storage, of providing or changing at terminal locations immediate update to codes, tables, matrices, remarks, and ASPR references.

8. Ability to generate only the specific clauses required for tailoring individual contractual instruments, thus obsoleting all "boilerplating".

9. Ability to generate: The DD-350; solicitation (SIIN), award (PIIN), and DD-350 registers; Delivery Order Header Report; distribution list; and other management reports simultaneously with the production of the award instruments.

10. Ability to reduce printing and paper required for contractual preparation as a result of the rearrangement of sections of the ASPR Uniform Contract Format and to allow detachment of certain sections required for solicitation but not required to be physically furnished with the award instrument.

The PADD System milestones project prototype testing and training to be conducted by the command in late 1977 with implementation scheduled for late spring 1978.

G L O S S A R Y

ACRN - Accounting Classification Reference Number.

ADP - Automatic Data Processing.

AUTOVON - Automatic Voice Network.

Boilerplate - Bringing together standard ASPR clauses normally required in the majority of awards and printing in suquence for attachment to the other sections of the award instrument.

CAO - Contract Administration Office.

CAO ADP Point - Contract Administration Automatic Data Processing Point.

CLIN - Contract Line Item Number - (Used to encompass Line Item Number, Contract Sub-Line Item Number, and Exhibit Line Item Number).

CCSS - Commodity Command Standard System.

DARCOM - Department of Army Materiel Development and Readiness Command.

DLA - Defense Logistics Agency.

DMIS - Directorate for Management Information Systems.

DoD - Department of Defense.

DoDAAD - Department of Defense Activity Address Directory.

FSCM - Federal Supply Code for Manufacturers.

GAO - General Accounting Office.

MAD - Materiel Acquisition and Delivery.

MILSCAP - Military Standard Contract Administration Procedures.

MILSTRIP - Military Standard Requisitioning, Receipt, and Issue System.

MMF - MILSCAP Master File.

MSC - Major Subordinate Command.

NSN - National Stock Number.

PADDS - Procurement Automated Data and Document System.

PRON - Procurement Request Order Number.

P/WD - Procurement/Work Directive.

SABL - Standard Automated Bidders List.

SDA - Source Data Automation.

UCF - Uniform Contract Format.

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3. Headquarters, DARCOM Memorandum, dated 6 June 1975, Subject: Word Processing.

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5. Headquarters, DARCOM Letter, dated 8 October 1975, Subject: Computer Support for Procurement and Production Directorate.

6. Headquarters, DARCOM Letter, dated 19 November 1975, Subject: System Concept Document for Mini-Computer Support of the P&P Area of MSC's.

7. Headquarters, DARCOM Letter, dated 7 July 1976, Subject: Detailed Functional System Requirement (DFSR) - Procurement Automated Data and Document System (PADDS).

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<u>The Systems Approach</u>, Thomas D. McGrath, publication and date unknown.

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PROCUREMENT QUALITY REVISITED - AN ALTERNATIVE APPROACH TO THE PROCUREMENT INTEGRATED QUALITY ASSURANCE (PIQUA) SYSTEM

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INTRODUCTION

In the Spring 1974 volume of the National Contract Management Journal Dale McNabb discussed a statistically oriented quality assurance system implemented by the Directorate of Procurement and Production at Sacramento Air Logistics Center (SM-ALC), Air Force Logistics Command.[1] At that time the Directorate of Procurement and Production at Oklahoma City Air Logistics Center (OC-ALC) was searching for an effective means of measuring the quality of its contractual actions. Since numerous indicators were available to measure timeliness of processing procurement actions, managers could easily determine where delinquencies were occurring and what was causing them. Unfortunately, they could not as readily identify quality problems and pinpoint their source. Too often they relied upon external criticisms of procurement quality. These criticisms were generated by the Procurement Committee and by self-inspection teams. The Procurement Committee had traditionally been responsible for contractual quality. Thorough reviews of contracts over $200,000 were performed by experienced analysts. Not so thorough reviews of contracts under $200,000 were performed by a less experienced technician. While all contracts over $200,000 were reviewed, only a very small sample of the smaller buys were scrutinized. If some area of the procurement operation was considered deficient by the Inspector General (IG) or some other outside critic, self-inspection teams were established to examine the buying divisions to determine if the reported problems were present. The number and percent of contractual actions reviewed were left to the discretion of each team; i.e., scientific sampling was non-existent. Equally uncoordinated was the resolution of these problems. These ad hoc groups frequently lacked the expertise necessary to identify the causes of IG findings. Therefore, the immediate supervisor was directed to make whatever changes he considered necessary to correct deficiencies in his own organization.

Unfortunately these various systems of quality measurement were never effectively coordinated; i.e., no one gathered all of the findings together for the purpose of identifying trends and suggesting corrective action. This piecemeal approach resulted in duplication of effort and an incoherent picture of procurement quality. What was needed was an integrated quality improvement system based on statistical sampling procedures. With such a system managers could isolate the areas which were most deficient and focus their attention on problems that offered the greatest potential for cure. Instead of attacking all of the problems all of the time, they could concentrate their resources in the areas offering the greatest return on investment.

The Procurement Integrated Quality Assurance System (PIQUAS) used at SM-ALC appeared to be a more efficient means to measure quality. The advantages of PIQUAS were its statistical sampling techniques and review sheets made up of objective questions which could be answered "yes" or "no". Disadvantages included the time-consuming detailed analyses performed on each discrepant file and the small number of contracts included in each month's sample. After thorough study of PIQUAS, the Director at OC-ALC decided to adopt a similar

quality assurance system. In contrast to SM-ALC, OC-ALC planned to review the largest sample possible and to identify trends rather than perform a detailed analysis of each file. The purpose of this paper is to illustrate Oklahoma City ALC's adaptation of the PIQUA System and to describe the results achieved.

DESIGNING THE PROGRAM FOR IMPROVEMENT OF CONTRACTUAL ACTIONS (PICA)

As indicated by the introduction, the basic objective of PICA was efficient problem identification. In order to achieve this goal, various elements, such as specificity, relevance, and significance, were incorporated to guarantee optimal results from the proposed quality system. Management already knew that contractual actions were not perfect. What they needed to know was what the precise problem was and where it was occurring. Supervisors wanted to stop training all buyers if 90 percent were complying with policy and procedures. Therefore, the PICA data file was designed to produce specific information; i.e., errors could be identified by section and by contracting officer.

Another element, relevance, was essential to the success of PICA. The attributes selected for review had to apply to a significant portion of the contractual actions. In order to invest resources in an efficient manner, managers needed to identify procurement tasks which would occur frequently in the sample being reviewed. They did not like to waste their time on problems that arose in only very rare instances.

Finally, significance became an important component of PICA. Managers wished to evaluate the impact of errors on the procurement process and to determine if corrective action would be worthwhile. Among their considerations were the likelihood of a protest or dispute, the question of equity, and the identification of substantive errors as opposed to errors of form.

SELLING PICA

Although PICA was designed to assist managers, the monitor at OC-ALC felt the success of the program depended upon how well it was received by buyers/contracting officers--the "victims". In order to sell PICA, the monitor sent a representative to the buying divisions to give informal briefings. This personal touch definitely contributed to their acceptance of the program. In fact, the PICA analyst has become an ombudsman of sorts. Buyers frequently request her assistance in solving problems they are having with local policies. The results of this dialogue have been amazing. At least ten different policy areas were redefined in the first eight months PICA was in operation. For example, several ambiguous general provisions were presenting problems in interpretation. The language of some of the clauses conflicted with the instructions spelled out in the applicability statement. In order to solve this problem, the ALC requested AFLC's assistance in clearing up these ambiguities. As a result of the request, AFLC submitted an ASPR case to correct the applicability statement for ASPR clause 7-104.15, "Examination of Records by Comptroller General."

Another illustration of PICA's effectiveness in clarifying fuzzy areas of policy is verification of bids/offers. When the error rate on the attribute measuring this task first exceeded the acceptable quality level, the problem was discussed in detail in the monthly PICA analysis. Clear-cut guidance was

given on handling suspected mistakes, and all buyers who incorrectly handled a suspected mistake were asked to discuss the situation with the ALC monitor for Public Law 85-804 and ASPR 2-406.4. Some very productive learning resulted from these sessions as shown by the substantial improvement in the error rate on that attribute from 20 percent in July 1976 to 6.3 percent in February 1977.

As demonstrated by the above examples, PICA has become a learning device for both the buyer and the reviewer. The buyer is forced to take time to study ASPR and other procurement directives, and the reviewer is able to see the obstacles certain policies are creating.

ATTRIBUTE CHECKLISTS

When developing the inspection sheets, OC-ALC's procurement managers elected to use attributes which had received criticism from various inspection teams. All available inspection reports were reviewed, and those criticisms which were considered serious enough to merit management surveillance were incorporated in the attribute checklists. Also, questions were developed to measure compliance with newly implemented policies. The attributes are objective questions which can be answered "yes" or "no". For example, "Are proposed procurements synopsized not later than the date of issuance of the solicitation?" Although not all questions are applicable to all actions reviewed, care was taken to insure that the attributes were of a general nature and would apply to a large enough sample of actions to be statistically valid. To better achieve this objective, separate checklists were developed for each type of contractual action; i.e., small purchases, contracts over $10,000, and modifications. The checklists illustrated in Exhibits 1 though 4 remain in use for a 12-month period. At the end of that time they are reviewed and purged of invalid attributes. Questions which are deleted include those which (1) have not exceeded the acceptable quality level, i.e., are not considered to be discrepant, (2) do not have a large enough sample for statistical validity, and (3) are no longer useful measures of quality regardless of the error rate or sample size. As a result of the first year's review, 63 attributes were deleted, 35 were added, and 18 were retained. This major revamping of the checklists was due to the fact that PICA's first year of operation was largely experimental with the majority of the attributes proving to be unsuitable.

STATISTICAL ANALYSIS

In the PICA system randomly selected contracts are examined to determine if specific procurement tasks have been performed correctly. These tasks, which are called attributes, are rated as either discrepant or not discrepant by the reviewer. The purpose of the exercise is to compute the error rate of the sample and to estimate the error rate of the total population. This information is printed out in the format shown in Exhibit 5. Statistical analysis of the sampled attributes is based on the binomial distribution which is a discreet theoretical distribution of a series of independent yes/no responses. The computer program uses sample data on the number of discrepancies for each attribute and the number of times the attribute is sampled. A likely upper limit (90 percent confidence) of the error rate for the total population is computed for each attribute based on the sample data. As the sample size increases, the probable error rate for the entire population of the attribute approaches the true population error rate. For samples of 30 or larger a very

accurate estimate of the total population error rate can be made from the sample error rate statistic.

MONTHLY PICA REVIEW

A simple statistical program was developed to determine the number of files to be pulled from the total population of files in order to insure a valid sample. The first 12 months PICA review covered 2081 actions and 19,118 individual attributes. The appropriate attribute checklist is completed for each file. All discrepancies are discussed with the contracting officer/buyer. In some cases this feedback has convinced the reviewer that the buyer has a valid position and the discrepancy is removed. In fact, the dialogue between the reviewer and the buyer/contracting officer has definitely contributed to the humanization of PICA by promoting friendlier attitudes among the "reviewees".

The results of the PICA review are furnished to all levels of supervision on a monthly basis. The monthly analysis, as represented in Exhibit 6, provides a directorate overall error rate as well as a section level error rate for each attribute reviewed. It also includes a discussion of the problems encountered and their suggested solutions. This monthly analysis is possible because PICA has been mechanized. The results of the monthly review are input into the CREATE computer and a statistical report is produced which states the 90 percent confidence limit and sample error rates for each attribute. Both overall directorate and individual section error rates are computed. An arbitrary rate is selected as the acceptable quality level (AQL) and directorate performance is measured against this AQL. Corrective action is directed for those attributes which exceed the AQL. This action ranges from simply discussing the problem in the monthly analysis to actually changing unworkable policies and procedures.

At times special training courses are developed to assist buyers who are having difficulties with specific procurement tasks. These courses are part of the Proficiency Enhancement Training (PET) Program which operates in tandem with PICA. The Directorate Training Monitor is advised of significant training needs which surface during PICA reviews and designs courses to cover these needs. Brief video tape cassettes are used extensively. Instead of having an expert give numerous lectures on the same subject, the presentation is taped and then replayed in the various organizations which PICA has identified as having a need for refresher training on a specific subject.

PICA RECOGNITION PROGRAM

To add incentive to PICA the Director has established a recognition program based on quarterly PICA error rates. Each quarter the section with the lowest overall error rate on PICA attributes is given an award. The program is designated the "PICA Ace" Award and the Snoopy Flying Ace figure is used as the theme. Using a "fun" theme and an objective selection criteria enhances the effectiveness of the award. The theme helps make PICA more palatable to buyers/contracting officers while the objective basis for recognition (PICA error rate) lends respectability to the award. The PICA Ace Program encourages competition among the sections which in turn improves the directorate error rate.

ASSESSMENT

While most of the advantages of PICA have been discussed previously, they need to be reiterated. The purpose in instituting PICA was to help procurement managers do a better job of managing. The monthly analysis is a management information system in the truest sense because it enables a supervisor to determine priorities. At a glance he can isolate the procurement tasks which are not being performed correctly in his section. If the error rate exceeds the acceptable quality level, he has various alternatives available to improve the quality of his buyers' contractual documents. He can require more extensive review of contracts prior to award, counsel individual buyers, discuss deficiencies in section meetings, or schedule Proficiency Enhancement Training.

In addition, since PICA identifies the problems offering the greatest potential for cure, the supervisor doesn't need to make value judgments each time he discovers a deficient area; if the task is covered by PICA, he gives it maximum attention. Thus PICA saves training hours and supervisory effort by focusing on major problems instead of taking a shotgun approach. It also serves as a training aid on major policy changes. Since some PICA attributes are designed to measure compliance with newly implemented policy, the monthly review is a constant reminder to buyers and helps speed up the learning curve.

Furthermore, PICA can be used in conjunction with other management indicators which measure contractual actions completed delinquent, processing time of buy actions, overage purchase requests, and efficiency. The supervisor can compare his buyers' performance in two important areas--timeliness and quality. For the first time he is able to determine if he is sacrificing quality for the sake of timeliness or vice versa. Of course, both are required for a successful procurement operation but trade-offs must occasionally be made between the two.

The most recent advantage of PICA to come to light is its capacity for reducing inspection and reporting burdens. The workload inherent in preparing for a visit by the AFLC Inspector General was considerably reduced because of PICA. Instead of performing independent reviews of an unscientific sample of contractual actions, the self-inspection group was able to consult PICA analyses to determine how we were doing in areas susceptible to review by the IG.

FOOTNOTE

[1]McNabb, National Contract Management Journal, Volume 8, No. 1, 141-153.

EXHIBIT 1

CONTRACT STANDARD INSPECTION SHEET
PROGRAM FOR IMPROVEMENT OF CONTRACT ACTIONS (PICA)
ATTRIBUTE CHECKLIST

	N/A	DISCREPANT YES	DISCREPANT NO
1. Does the synopsis accurately reflect the requirement and any option provisions? (AFLC ASPR Sup 1-1003.1; SM-ALC IG Finding 05, 25 Apr - 10 May 76)			
2. Are proposed procurements synopsized not later than the date of issuance of the solicitation? (ASPR 1-1003.2)			
3. Is ASPR exception 1-1003.1(iv) to synopsizing proposed procurements appropriately applied? (OC-ALC IG Finding 02, 9-24 Nov 75)			
4. Is the D&F signed by the appropriate official prior to issuance of RFQ or RFP? (PP Ltr, 20 Nov 74, Requirement for Determinations & Findings, Authority to Negotiate)			
5. Does the required delivery schedule in the solicitation conform with the PR need date? (WR-ALC IG Finding D02, 19 Sep - 4 Oct 76)			
6. Is the required delivery statement placed in competitive solicitations for PRs which have apparently unach'evable need dates? (PPOI 70-55 and OC-ALC IG Finding D6, 9-24 Nov 75)			
7. Is the required delivery statement placed in solicitations for urgent sole source buys? (PPOI 70-55 and OC-ALC IG Finding D6, 9-24 Nov 75)			
8. Are procedures contained in OC-ALC TAFBR 70-10 followed if PR is marked suitable for the packaging services contract? (PP Ltrs, 5 & 22 Apr 76, Procurement of Preservation and Packing Services)			
9. Are oral solicitations documented as required by ASPR 3-502(d)? (WR-ALC IG Finding D04, 19 Sep - 4 Oct 76)			
10. Is timely follow-up initiated on overdue solicitations? (PPOI 70-55; PP Ltr, 17 Dec 75, Follow-up Actions on Overdue Quotations; and OC-ALC IG Finding D7, 9-24 Nov 75)			
11. Are bids and offers being verified where the file indicates such action should be taken? (PP Ltr, 9 Mar 76, Contractor Requests for Relief under Public Law 85-804 and Mistakes in Bid)			
12. Are proposals marked by an official date stamp to reflect the time received in the directorate? (PP Ltr, 1 Sep 76, Date Stamping of Handcarried Proposals and TWX Proposals)			
13. Are late offers on competitive RFPs handled IAW ASPR 3-506? (WR-ALC IG Finding D8, 19 Sep - 4 Oct 76)			
14. Are requests for best and final offers made only when negotiations have actually been held and after all areas of disagreement have been resolved? Are all offerors within the competitive range given an opportunity to propose if there are changed conditions? (AFLC/PPP Ltr, 26 Ma. 76, Best & Final Offers; Problems and Guidelines)			
15. Is the reason for the nonresponsiveness of bids documented on the DD Form 1501, "Abstract of Bids"? (PPOI 70-29 and SM-ALC IG Finding D02, 25 Apr - 10 May 76)			
16. Do price negotiation memorandums prepared by buying divisions adequately support determination of fair and reasonable price? (PPOI 70-11; PP Ltr, 17 Dec 75, Pricing Responsibilities and Supporting Documentation; and OC-ALC IG Finding D5, 9-24 Nov 75)			
17. Is award to other than low offeror made in accordance with PPOI 70-55?			
18. Are urgent purchase requests processed expeditiously? (OC-ALC IG Finding D4, 9-24 Nov 75)			
19. Are current procedures followed relative to preaward notice of apparently successful offeror on small business set-asides? [ASPR 3-508.2(b)]			
20. Is response made to SJA comments when appropriate? (PPOI 70-67; OC-ALC IG Finding D02, 9-24 Nov 75; and PP Ltr, 18 Apr 75, Participation of The Staff Judge Advocate in the Procurement Process)			
21. Is coordination completed with the item manager when the need date is not met? (PPOI 70-55 and OC-ALC IG Finding D02, 9-24 Nov 75)			
22. Does the award require submission of a disclosure statement per ASPR 3-1203? (PP Ltr 19 Feb 76, Cost Accounting Standards Disclosure Statements)			

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EXHIBIT 2

CONTRACT STANDARD INSPECTION SHEET
PROGRAM FOR IMPROVEMENT OF CONTRACT ACTIONS (PICA)
ATTRIBUTE CHECKLIST
(BASE PROCUREMENT)

	N/A	DISCREPANCY YES	DISCREPANCY NO
2. Are proposed procurements synopsized not later than the date of issuance of the solicitation? (ASPR 1-1003.2)			
3. Is ASPR exception 1-1003.1(iv) to synopsizing proposed procurements appropriately applied? (OC-ALC IG Finding D2, 9-24 Nov 75)			
9. Are oral solicitations documented as required by ASPR 3-501(d)? (WR-ALC IG Finding DD4, 19 Sep - 4 Oct 76)			
11. Are bids and offers verified where the file indicates such action should be taken? (PP Ltr, 9 Mar 76, Contractor Requests for Relief under Public Law 85-804 and Mistakes in Bid)			
12. Are proposals marked by an official date stamp to reflect the time received in the directorate? (PP Ltr, 1 Sep 76, Date Stamping of Handcarried Proposals and TWX Proposals?			
13. Are late offers on competitive RFPs handled in accordance with ASPR 3-506? (WR-ALC IG Finding DB, 19 Sep - 4 Oct 76)			
14. Are requests for best and final offers made only when negotiations have actually been held and after all areas of disagreement have been resolved? Are all offerors within the competitive range given an opportunity to propose if there are changed conditions? (AFLC/PPP Ltr, 26 Mar 76, Best and Final Offers Problems and Guidelines)			
15. Is the reason for the nonresponsiveness of bids documented on the DD Form 1501, "Abstract of Bids"? (PPOI 70-29 and SM-ALC IG Finding DD2, 25 Apr - 10 May 76)			
16. Do price negotiation memorandums prepared by buying divisions adequately support determination of fair and reasonable price. (PPOI 70-11; PP Ltr, 17 Dec 75, Pricing Responsibilities and Supporting Documentation; and OC-ALC IG Finding D5, 9-24 Nov 75)			
19. Are current procedures followed relative to preaward notice of apparently successful offeror on small business set-asides? (ASPR 3-508.2(b))			
20. Is response made to SJA comments when appropriate? (PPOI 70-67; OC-ALC IG Finding DD2, 9-24 Nov 75; PP Ltr, 18 Apr 75, Participation of The Staff Judge Advocate in the Procurement Process)			
23. Is contract award made after expiration of the contractor's acceptance period? (OC-ALC IG Finding D9, 9-24 Nov 75)			
26. Is written notice given to unsuccessful offerors/bidders promptly after award that their proposals/bids were not accepted including the reasons if award is made to other than the low offeror/bidder? (ASPR 2-408.1 and 3-508.3; SM-ALC IG Finding DD1, 25 Apr - 10 May 76)			
27. Does the contract file contain documentation as required by ASPR Supplement No 2, paragraph S2-102.1 and PPOI 12-1? Are files in correct sequence? Are there loose documents, nonstandard size papers, illegible notes, unsigned/undated documents? (WR-ALC IG Finding DD4, 19 Sep - 4 Oct 76)			
28. Do IFBs for construction in excess of $25,000 contain a liquidated damages provision as required by ASPR 18-113? Is the amount consistently calculated? (WR-ALC IG Finding DD12, 19 Sep - 4 Oct 76)			

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EXHIBIT 3

CONTRACT MODIFICATION STANDARD INSPECTION SHEET
(PR GENERATED)
PROGRAM FOR IMPROVEMENT OF CONTRACT ACTIONS (PICA)
ATTRIBUTE CHECKLIST

	N/A	DISCREPANT	
		YES	NO
66. Does the synopsis accurately reflect the requirement and any option provisions? (AFLC ASPR Sup 1-1002.1 and 1-1003.1; SA-ALC IG Finding D5, 25 Apr-30 May 76)			
67. Is ASPR exception 1-1003.1(iv) to synopsizing proposed procurements appropriately applied? (OC-ALC IG Finding D2, 9-24 Nov 75)			
68. Do price negotiation memorandums prepared by buying divisions adequately support determination of fair and reasonable price? (PPOI 70-11; PP Ltr, 17 Dec 75, Pricing Responsibilities and Supporting Documentation; and OC-ALC IG Finding D5, 9-24 Nov 75)			
69. Are urgent purchase requests processed expeditiously? (OC-ALC IG Finding D4, 9-24 Nov 75)			
70. Is response made to SJA comments when appropriate? (PPOI 70-67; OC-ALC IG Finding D02, 9-24 Nov 75; and PP Ltr, 18 Apr 75, Participation of The Staff Judge Advocate in The Procurement Process)			
71. Is coordination completed with the item manager when the need date is not met? (PPOI 70-55 and OC-ALC IG Finding D02, 9-24 Nov 75)			
72. Does the award require submission of a disclosure statement per ASPR 3-1203? (PP Ltr, 19 Feb 76, Cost Accounting Standards Disclosure Statements)			
73. Are additional general provisions added to the purchase order upon issuance of the first bilateral modification in accordance with ASPR 3-608.4(a)(iii)? (OC-ALC IG Finding D8, 9-24 Nov 75)			
74. Is contract award made after expiration of the contractor's acceptance period? (OC-ALC IG Finding D9, 9-24 Nov 75)			
75. Does contract file contain documentation as required by ASPR Supplement No 2, paragraph S2-102.1 and PPOI 12-1?			
76. Are changed conditions set forth in the format required by AFLC ASPR Supplement 26-101.50?			

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EXHIBIT 4

SMALL PURCHASE STANDARD INSPECTION SHEET
PROCUREMENT INSPECTION OF CONTRACT ACTIONS (PICA)
ATTRIBUTE CHECKLIST

	N/A	DISCREPANT YES	DISCREPANT NO
101. Is the required delivery statement placed in competitive solicitations for PRs which have apparently unachievable need dates? (PPOI 70-55 and OC-ALC IG Finding D6, 9-24 Nov 75)			
102. Is the required delivery statement placed in solicitations for urgent sole source buys? (PPOI 70-55 and OC-ALC IG Finding D6, 9-24 Nov 75)			
103. Does the required delivery schedule in the solicitation conform to the PR need date? (WR-ALC IG Finding D02, 19 Sep - 4 Oct 76)			
104. Are procedures contained in OC-ALC-TAFER 70-10 followed if PR is marked suitable for the packaging services contract? (PP letters, 5 & 22 Apr 76, Procurement of Preservation and Packing Services)			
105. Is timely follow-up initiated on overdue solicitations? (PPOI 70-55; PP Ltr, 17 Dec 75, Follow-up Actions on Overdue Quotations; and OC-ALC IG Finding D7, 9-24 Nov 75)			
106.* Are bids and offers verified where the file indicates such action should be taken? (PP Ltr, 9 Mar 76, Contractor Requests for Relief under Public Law 85-804 and Mistakes in Bid)			
107. Do price negotiation memorandums prepared by the buying division adequately support determination of fair and reasonable price? (PPOI 70-11; PP Ltr, 17 Dec 75, Pricing Responsibilities and Supporting Documentation; and OC-ALC IG Finding D5, 9-24 Nov 75)			
108. Is the reason for the solicitation of quotes from only one source stated in the PMR? (WR-ALC IG Finding D01, 19 Sep - 4 Oct 76)			
109. Is award to other than low offeror made in accordance with PPOI 70-55?			
110. Are urgent purchase requests processed expeditiously? (OC-ALC IG Finding D4, 9-24 Nov 75)			
111. Is coordination completed with the item manager when the need date is not met? (PPOI 70-55 and OC-ALC IG Finding D02, 9-24 Nov 75)			
112. Is file properly documented where cycle is changed from 4 to 5 and are necessary conditions present? (PP Ltr, 15 Oct 76, J041 System Cycle 5 Actions under $10,000.)			
113. Do the inspection criteria included in the contract conform with the requirements of the PR? If not, has QE/NM approved any changes? (ASPR 14-201)			
114. Does contract file contain documentation as required by ASPR Supplement No 2, paragraph S2-102.1 and PPOI 12-1? Are files in correct sequence? Are there loose documents, nonstandard size papers, illegible notes, unsigned/undated documents? (WR-ALC IG Finding D04, 19 Sep - 4 Oct 76)			

OC/SPF/42-1 77 JAN 1

EXHIBIT 5

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PROGRAM FOR IMPROVEMENT OF CONTRACT ACTIONS
PICA

DIRECTORATE OF PROCUREMENT AND PRODUCTION
OKLAHOMA CITY AIR LOGISTICS CENTER

****
****

REVIEW FOR MONTHS 7610 TO 7703

CONTRACT STANDARD INSPECTION
----

1 SYNOPSIS ACCURATELY REFLECT THE RQMT & OPTION?
===============

	MONTHLY DATA			CUMULATIVE DATA		
PP/SECT	SAMP.E/R	90%CONF.LIM	NO.APP	SAMP.E/R	90%CONF.LIM	NO.APP
PP TOTAL	.000	.068	44	.024	.048	165
ZAA	.000	.667	3	.000	.231	13
ZAB	.000	.273	11	.074	.222	27
ZEA	.000	1.000	1	.059	.235	17
ZEB	.000	.300	10	.000	.086	35
ZIA	.000	.667	3	.000	.300	10
ZIB	.000	.400	5	.000	.273	11
WAB	.000	.500	4	.000	.176	17
WAM	.000	1.000	1	.143	.571	7
WCA	.000	.333	6	.000	.115	26
WCD	.000	.000	0	.000	1.000	2

2 PROPOSED PRCMT SYNOPSIZED NLT ISSUANCE OF SOLICITATION?
===============

	MONTHLY DATA			CUMULATIVE DATA		
PP/SECT	SAMP.E/R	90%CONF.LIM	NO.APP	SAMP.E/R	90%CONF.LIM	NO.APP
PP TOTAL	.040	.120	50	.013	.033	159
ZAA	.000	.667	3	.000	.250	12
ZAB	.100	.400	10	.045	.132	22
ZEA	.000	1.000	1	.000	.214	14
ZEB	.000	.300	10	.000	.167	18
ZIA	.000	.667	3	.000	.300	10
ZIB	.000	.400	5	.000	.333	9
WAB	.000	.500	4	.000	.231	13
WAM	.000	1.000	1	.000	.333	6
WCA	.167	.667	6	.042	.167	24
WCB	.000	.000	0	.000	1.000	1
KC	.000	.000	0	.000	.333	6
KS	.000	.286	7	.000	.214	14

3 ASPR EXCEPTION 1-1003.1(IV) TO SYNOPSIZING PROPOSED PRCMT
APPROPRIATELY APPLIED?
===============

	MONTHLY DATA			CUMULATIVE DATA		
PP/SECT	SAMP.E/R	90%CONF.LIM	NO.APP	SAMP.E/R	90%CONF.LIM	NO.APP

EXHIBIT 6

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS OKLAHOMA CITY AIR LOGISTICS CENTER (AFLC)
TINKER AIR FORCE BASE OKLAHOMA 73145

2 JUL 1976

REPLY TO ATTN OF: PPC

SUBJECT: Program for Improvement of Contractual Actions (PICA) Section Analysis as of May 1976

TO: PPW PPZ PPD PPK

1. PICA data for May 1976 (both monthly and cumulative totals) is forwarded for your review. Please refer to PPC letter, 16 Mar 76, Program for Improvement of Contract Actions (PICA) Section Analysis for Oct, Nov, Dec 1975, for instructions on interpreting the data.

2. Management Review items for May will be attributes 9, 11/109 (combined) 20/76/114 (combined), 24/116 (combined), 29, 30/81 (combined), and 49. The attributes which have become statistically valid since our last report are 30, 68, 109, and 116. The previously reported attributes which are no longer discrepant are 20, 54, and 110. (Good work!!) As you can see by the following statistics, we are improving in all but four areas:

Attribute	Error Rate As of 7512	Error Rate As of 7601	Error Rate As of 7602	Error Rate As of 7603	Error Rate As of 7604	Error Rate As of 7605
7	55.4	47.7	46.1	46.5	37.4	36.0
9	-0-	-0-	6.3	4.8	31.0	33.3
14	20.5	20.4	17.2	15.4	11.8	10.3
20	13.2	12.2	11.7	11.5	10.3	9.6
29	3.2	4.5	5.3	12.8	13.3	16.2
30	50.0	57.1	57.1	57.1	44.4	57.1
49	33.3	42.9	33.3	28.6	20.7	17.1
54	45.5	28.6	20.0	16.2	12.2	8.7
68	-0-	-0-	5.6	14.8	12.5	10.3
76	12.5	25.0	28.0	23.1	21.8	21.5
78	-0-	9.5	11.8	12.2	11.7	11.3
109	7.7	5.9	14.3	14.8	16.1	21.2
110	7.5	7.5	11.0	11.2	10.3	9.0
114	14.7	13.1	13.5	11.9	11.4	10.5
116	-0-	4.8	12.5	14.8	15.6	13.9

3. The error rate for attribute 9, "Handling of First Article IAW Current Directives," continues to rise. Problems found in May are the same ones found in April. Since the attribute was discussed in our 9 Jun 76 letter, we expect improvement in June and July files.

4. The error rate for attribute 29, "File Properly Documented Where Cycle Change from 4 to 5 and Necessary Conditions Present," did not improve in May as predicted. It is apparent from the May data that four sections have successfully implemented PP letter, 6 Oct 75, J041 System Cycle 5 Actions Under $10,000, i.e., they have no errors. Perhaps the remaining six sections could improve their performance by adopting the procedures followed in PPZAA, PPZIB, PPWCA, or PPWCB.

AFLC - Lifeline of the Aerospace Team

5. Attribute 30, "Does Award Require Disclosure Statement Per ASPR 3-1203?," became statistically valid this month. ASPR 3-1203 requires that the contractor, with some exceptions, submit one of the certifications outlined in ASPR 7-2003.67(a) with each offer which could result in a negotiated contract exceeding $100,000. In addition, the PCO must obtain a statement from the ACO regarding the adequacy of the contractor's disclosure statement. In accordance with PP letter, 19 Feb 76, Cost Accounting Standards (CAS) Disclosure Statements, PPF is asking for the ACO statement in each request for DCAA audit and field pricing assistance and is insuring that the ACO's position is discussed in the Price Negotiation Memorandum. However, it is the PCO's responsibility to obtain the ASPR 7-2003.67(a) certification from the contractor. The latter requirement is presenting difficulties to buyers/PCOs. If solicitations are made by SF 33, the Disclosure Statement - Cost Accounting Practices and Certification (1975 Dec) (OC/UCF/B-5 and B-6) is included. When the buyer solicits by TWX in contemplation of award by BOA order, he or she can easily forget to request the disclosure statement certification. In order to correct this situation PPC has drafted a disclosure statement certification which is to be added to local BOAs by supplemental agreement. In addition, we are advising AFLC and the other ALCs of the need for this addition to the Uniform BOA Format. In the meantime, buyers will need to include a request for the disclosure statement certification in solicitations expected to result in a negotiated BOA order over $100,000. OC/SPF-10-1 and OC/SPF-10-2 could be included in written solicitations or mailed at the same time a TWX solicitation is transmitted.

6. Attribute 68, "Small Business Sheet in Error or Incomplete," has exceeded the minimum acceptable quality level (AQL) for the past three months. Mistakes, which have been very minor, include incorrect PR estimate in block 1, no PR/MIPR number in block 2, erroneous information in block 4, and inappropriate negotiation authority in block 8.

7. Problems have also surfaced with attribute 109, "Determine if Bids and Offers Are Being Verified Where Indicated." Although PPC has been providing guidance to buyers whose files have discrepancies, we feel that additional emphasis is needed. In the past three years at least three letters have been written to provide guidance on verification of bids and offers (PP ltr, 7 Feb 73, Verification of Bids and Offers; PPC ltr, 14 Aug 74, Verification of Prices on Suspected Mistakes; and PP ltr, 9 Mar 76, Contractor Requests for Relief under Public Law 85-804 and Mistakes in Bid). The first two letters were rescinded because they had served their purpose. Unfortunately, it appears that the adage, "out of sight, out of mind," applies. Therefore, the following comments are offered to assist buyers/PCOs in discharging their responsibilities. ASPR 2-406 requires that when a buyer/PCO suspects a mistake in a contractor's bid, he shall request the prospective contractor to verify his price, "calling attention to the suspected mistake." The adequacy of this verification is addressed in Comptroller General Decision B-177405 which states, in part:

"In order for a request for verification to conform to the good faith dealings expected of the Government's contracting officials, the request should be as fully informative as possible concerning the pertinent factors indicating to the contracting officer that an error was made in the bid."

The contract file must be well-documented as to the efforts taken by the buyer/PCO to alert the contractor to the suspected mistake, including the basis for the suspicion, i.e., the bid or offer is out of line in comparison with others, with previous prices paid, or with the Government estimate. Although ASPR, Part 3, does not demand this verification in negotiated procurements, it is inherent in prudent business practice to inform a low offeror that his offer is out of line. Should the successful contractor, after award, then allege a mistake and request relief under Section XVII of ASPR (PL 85-804), the Government would be in a position to deny relief. Failure to resolve apparent or suspected mistakes prior to award causes the Government to contribute to the mistake and may result in the contract being reformed or rescinded with concomitant delivery problems.

8. Finally, attribute 116, "Policy of PPOI 70-79 and PP Letters Followed in Procurement of Overhaul Parts Repair Kits," has become statistically valid for the first time this month. The only apparent stumbling block with kit buys is remembering to include the required clauses in competitive solicitations (OC/SPF/PO-2-3) and resultant awards (OC/SPF/PO-2-2). Since long-standing procedures have recently been changed, buyers/PCOs should be cautioned to review PPOI 70-79 dated 9 June 1976 for current policy.

9. All other discrepant attributes have been discussed previously. With eight months of data collected, 55 of 81 PICA attributes have become statistically valid. Of the 55, only 12 exceed the acceptable AQL of 10%.

1 Atch
Section Analysis

Cy to: Branches and Sections

MIL-STD-1567(USAF): THE BILLION DOLLAR PAYOFF

Don A. Moore
Kirtland AFB, New Mexico

INTRODUCTION

This paper describes the cycles of needs, research, and implementation efforts necessary for the development of MIL-STD-1567(USAF), Work Measurement, and the use of MIL-STD-1567(USAF) to achieve cost reductions in the acquisition of major USAF weapon systems. This description is presented for two reasons. The first is to demonstrate the potential of MIL-STD-1567(USAF) for immediate improvement in manufacturing performance. The second is to provide a prototype success story of a procurement research project. The moral of the prototype procurement research success story is that for procurement research to be successful requires a commitment and dedication to continuing research and implementation efforts. This effort also requires the education of management sufficient to create the climate that makes possible implementing the research.

The model used to describe the research process and used as the format to describe the efforts to develop and implement MIL-STD-1567(USAF) is depicted in Figure 1 below. The events described in the format so depicted are not necessarily in true chronological order. As in applying all models, there is in reality a blending of the steps that are depicted as discrete. Needs, implementation efforts, and research are, in some cases, integrated and indistinguishable. This reinforces the moral of our story -- that procurement research, to be successful, requires continuing research and implementation efforts.

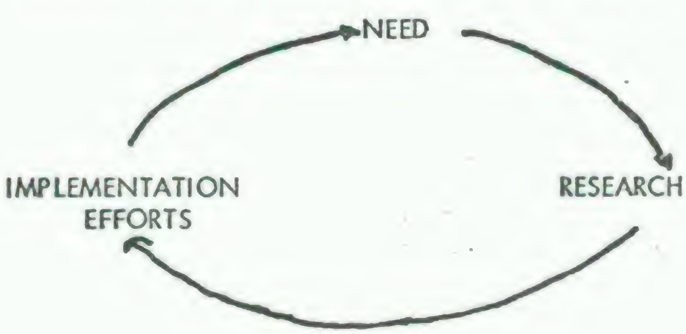


Figure 1

This model depicts an iterative cycle. Whether or not the iterative process converges depends on the extent to which each step of the process continues to focus on the end results that must be achieved to truly meet the original need. Therefore, the model for a successful research process is the one depicted below in Figure 2.

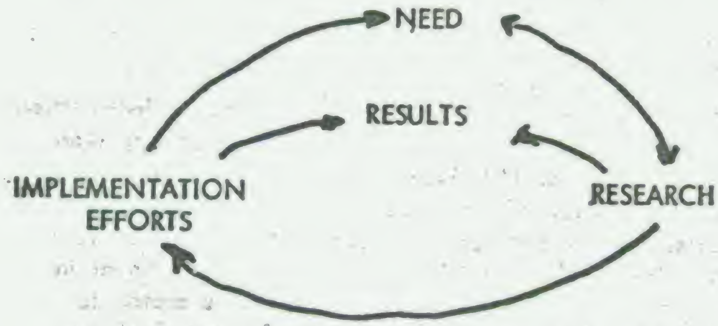


Figure 2

The results, in the case of MIL-STD-1567(USAF), would be the lowering of the costs of acquiring major Air Force weapon systems through improving contractor direct manufacturing labor productivity and other improvements incidental to the disciplined use of an effective work measurement and methods improvement system.

Need

Simply stated, the need is to lower weapon system hardware costs. The Air Force and Department of Defense concern for the spiraling cost increases fosters almost continuous study and research in how to reduce or better control such cost increases. The need has been exacerbated by relative and absolute declines in the proportion of the budget and national product devoted to Defense. Continuing inflation plus the steady increase in personnel costs during the last decade further increased the pressure to get the most out of our hardware dollars. Furthermore, it appears that the public perception of the efficacy of Defense spending resulted in decreased support for such spending over much of the last decade.

In reality, the need appears to be somewhat greater than simply lowering hardware costs. The need appears to be to demonstrate the

efficacy of Defense spending. In the area of new Air Force weapon systems acquisitions, this means not only must costs be reduced or controlled, but the management must be demonstrably effective and efficient.

Research

To abbreviate somewhat a rather lengthy story, only a sampling of key studies will be presented.

In 1970, the Manufacturing Committee of the Aerospace Industries Association conducted a survey from which the following conclusions were made:

"1. Among respondents there is almost universal use of standards for labor planning and control of production labor, and in addition two-thirds of the respondents use standards for measuring some portion of the indirect-type or manufacturing support activities. Those who use standards for other than production labor vary widely in the types of activities covered by standards. There appears to be considerably less activity and/or success in measuring indirect labor.

"2. Organizational placement appears to have little to do with respect to standards effectiveness as shown by reported savings vs costs ratios. Among respondents who claim knowledge of their savings vs costs, ratios vary from 2:1 to over 5:1.

"3. Companies with highest savings vs costs ratios tended to measure by group and also tended to use standard time data.

"4. Labor performance reports on a weekly basis are by far most common.

"5. Allowances for personal, fatigue and delay time average around 13% with none reported below 5% and none above 22.5%.

"6. It is envisioned that in the future standards will be used more extensively for such purposes as computerized shop loading, product and equipment design evaluation, and indirect labor measurement.

"7. Standards are normally communicated to supervision and production workers. One-third of the respondents use operator performance to standards for disciplinary action.

"8. Seventy-five percent of the respondents use electronic data processing terminals for data collection and a like percentage provides for non-productive labor and delay reporting.

"9. Among the respondents, about 72% of production labor hours are covered by engineered standards with a marked indication of planned increase of coverage and no planned decrease.

"10. Data from respondents indicated that personnel responsible for establishing and maintaining standards systems tend to be somewhat satisfied with current techniques and collectively envision a need for more of the same. This may be an unrealistic approach, particularly with the low production quantities associated with most current aerospace programs." (1)

The Lyon's (for then Brigadier General Herbert A. Lyon, Deputy Chief of Staff, Systems, Air Force Systems Command, Study Director) Study, formally known as the Air Force Production Management Study, was also conducted in 1970. One of that study's conclusions and recommendations was, "Contractual instruments have not contained definitized requirements for effective control of the production process." (2)

As the result of the Lyon's Study, MIL-STD-1528(USAF), Production Management, was created. One unelaborated requirement of this standard was for the "Maintenance of a work measurement program." (3) In addition to incorporating MIL-STD-1528(USAF), the A-10 contract contained a somewhat more elaborate requirement for work measurement:

"The contractor shall have and use a system of measuring the efficiency of departments engaged in the manufacturing process. He will insure that the system provides this measurement at the lowest available work center permitting compilation of efficiency rating to the department level. Criteria to be used shall include: labor productivity, amount of scrap, amount of re-work, housekeeping record, safety record, amount of waste, amount of machine down time, shop loading record, planning error record, and scheduled job completion record. Contractor shall also insure that accurate labor time standards exist and are used to assess productivity of all departments engaged in the manufacturing process. He will ensure that labor time standards are provided for each operation element of work required of a worker. Variance reports will be issued monthly showing the actual versus standard performance achieved (summation level) at the lowest available work center. Compilation of individual work center variance will be used to gain job and

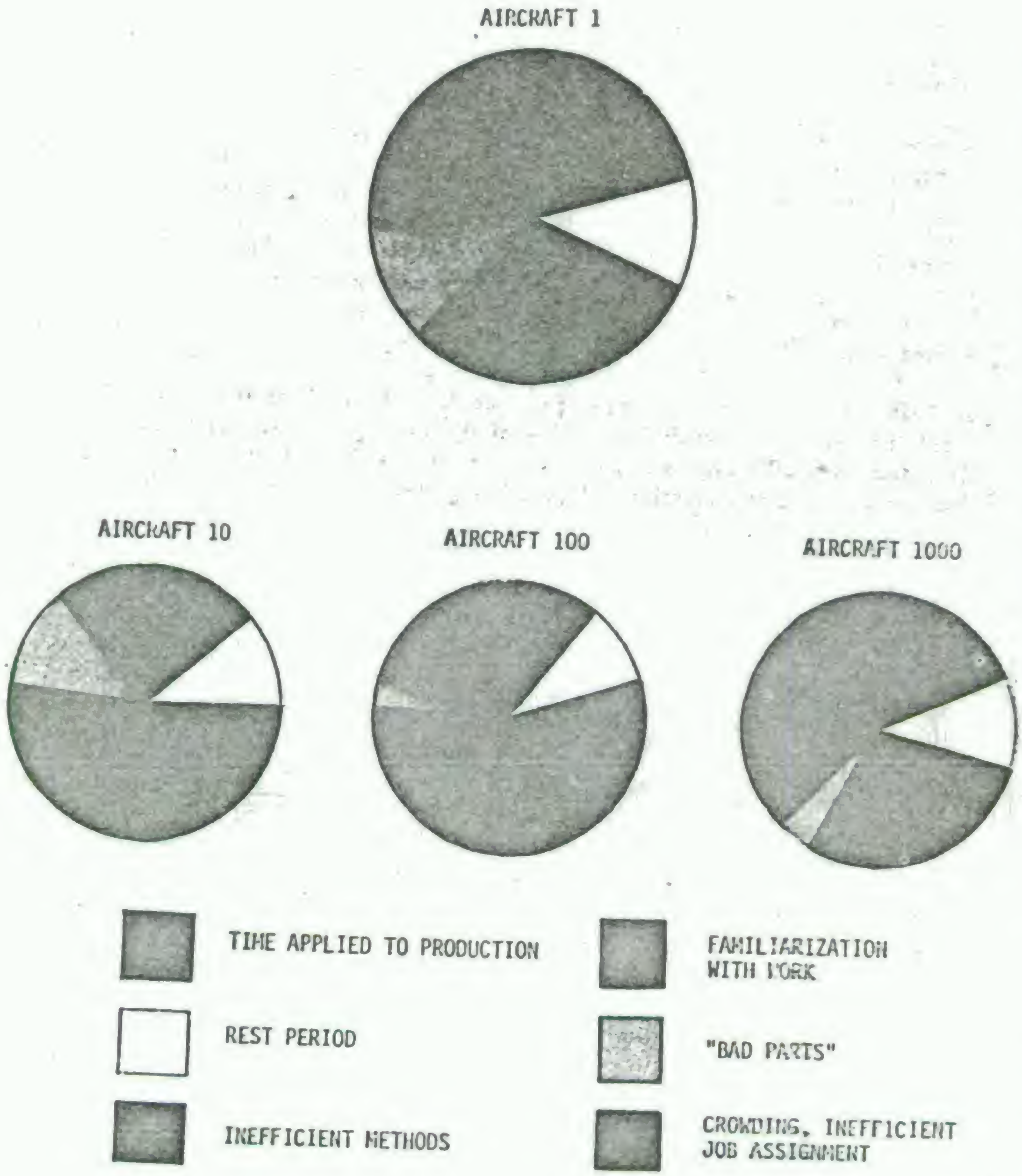
departmental variance data. The labor time standards along with reasonable variance targets will also be available to contractor cost estimating personnel and will form a basis for manufacturing cost estimates. The contractor will ensure that this labor productivity data is provided as an input to the departmental efficiency system. Acceptable variances, in accordance with industry standards, will be set to insure optimum labor productivity at all levels or departments engaged in the manufacturing process. The contractor shall use this information to most efficiently manage and control the manufacturing departments. The system procedures, and any subsequent changes shall be coordinated with the local Government representative prior to implementation." (4)

In 1972, the so-called Sagamore Study provided the basis for the statement that even at Aircraft 1000, 45% of the time was non-productive.(5) The study was officially published as the Summary of Air Force/Industry Manufacturing Cost Reduction Study, 28 August-1 September 1972, Air Force Materials Laboratory Technical Memorandum AFML-TM-LT-73-1, January 1973. Figure 3 below is developed from the information in that study.

There are several interesting inferences that can be made from Figure 3. The first concerns inefficient methods. The inference is simply that there is significant potential to improve productivity by methods improvement, especially by carefully defining the methods right from the start. By doing that, by better defining methods initially, the amounts of time consumed by familiarization with work, and crowding would be drastically reduced; inefficient job assignment should also decrease.

The factors that affect productive time, such as bad parts, inefficient methods, and crowding, inefficient job assignment are primarily management responsibilities as opposed to worker or operator responsibilities. To some considerable extent, management is also responsible to see that training, supervision, and clarity of work instructions minimize the time required for familiarization with the job.

Familiarization with the job is representative of learning -- in the context of learning curves. The phenomenom of learning has been described mathematically in terms of production time decreasing by a fixed percentage as production quantities double. Aerospace schedules and budgets traditionally reflect this phenomenom. Often for



MAN-HOURS EXPENDED ON A TYPICAL ASSEMBLY

Figure 3

purposes of estimating, the time to make the initial production units are calculated by figuring that the engineered time standards or efficient production will be achieved at Unit 1000 or 5000 or so. Then the estimate for the early production units are created by "backing up" the learning curve. If the standard was to be assumed to be met at Unit 1000 and an 84% curve were used (that is as quantities double, the unit production time decreases to 84% of the earlier units' production time), then the initial estimate would be about 5.7 times the thousandth unit or the target for efficient production.

In reality, as can be seen from Figure 3, the phenomenom is not so much one of learning as one of cost improvement. Production efficiency increases more as a result of other factors than as a result of learning or familiarization with work. In fact, after the first dozen units or so, familiarization with work does not become a significant cause of inefficiency. Therefore, one could conclude from Figure 3 that an operator does not have to work on thousands of aircraft before there is hope of achieving performance to an engineered standard because, by definition, an engineered standard is the time it should take a reasonably skilled operator to do a job he is familiar with.

Implementation Efforts

On 25 March 1973, General George Brown, who was then Commander of Air Force Systems Command, chartered Project ACE (for Acquisition Cost Evaluation). (6) One of the results of the project was the identification of an opportunity for potentially significant savings in direct manufacturing labor on major weapon systems, based on the Sagamore Study. Consequently, Air Force Contract Management Division was tasked to develop a military standard for work measurement. (7) The standard was to be designed to require disciplined and integrated work measurement systems as a vehicle to achieving reductions in direct manufacturing labor and other costs.

The original AFCMD effort, dated 4 January 1974, contained the following provisions that were later modified:

Type I (engineered) standards to have an accuracy of ±10% with 95% confidence.

A plan to provide for progress toward a goal of 90% coverage of touch (direct manufacturing) labor by Type I standards.

Contractor to take full advantage of the standard time data available in the DOD Data Bank.

The Government to retain rights to all basic and multipurpose standard time data developed under contracts of which this standard is a part. (8)

The draft standard was submitted to AFSC by AFCMD and subsequently submitted to industry for coordination. This established a series of interactions ultimately involving AFCMD, AFSC, DOD, and professional and industry association representatives. The objective was to produce a professionally sound, effective, workable standard acceptable to both the Air Force and industry.

The initial industry response came through the Council of Defense and Space Industry Associations (CODSIA). That response is summarized below:

Appreciation of the opportunity to review the proposed standard.

Concurrence with objective of obtaining maximum productivity and cost effectiveness while fulfilling contractual requirements.

Concern that the standard represented another layer of management discipline and control.

Objections that the standard was vaguely specified, structurally complex, extremely burdensome to install and maintain, administratively expensive, redundant to existing contractually required management systems, and contrary to DOD expressed policy.

Emphasis that the proposed standard "would infringe on a private company's right to manage its own business so as to pose a threat to our competitive economic system. Moreover, the imposition of 'socialized' standards on industry would have the effect of stifling competition between companies, contrary to the design to cost concepts and value engineering."

Expression that, "the government's desire for reduced cost can best be attained through contractor competition, not government imposed performance measurement."

Contention that the Project ACE indictment of aerospace industry manufacturing inefficiencies was unwarranted.

Summarization that management techniques must be determined on a case-by-case basis and are best left to the discretion of individual company management.

Emphasis that industry currently uses work measurement.

Contention that current controls are generally adequate.

Recommendation that the standard need not and should not be issued. (9)

Need

A new need was created. This was the need to resolve industry concern sufficiently to get a military standard published.

Research

Commercial light plane manufacturers' practices and those of the aerospace industry were reviewed. We literally searched again through old studies and records, as well as initiating new investigations. This research was designed in reality to reassure ourselves that our work made sense.

One reassuring criticism received was that the proposed military standard represented a textbook, motherhood approach to work measurement. It was our intention that the military standard be just that, and more. The "more" was that it must be implementable.

Implementation Efforts

Our approach was to promote understanding. To that end, AFCMD participated in and/or fostered the following activities:

The development of a Work Measurement Systems Evaluation Course to teach the Government representatives in plant the techniques they would need to administer the provisions of the Work Measurement Military Standard in a contract. This course is taught by the Army Management Engineering Training Agency (AMETA). Thus far, four classes of about twenty each have been taught.

A seminar at one contractor's facility detailing how the MIL-STD might be implemented there.

Presentations at American Institute of Industrial Engineers (AIIE) Chapter meetings in Los Angeles and Orange County, at the AIIE Aerospace Division National Conference, and at the AIIE National Conference in 1977.

Presentations at the Spring and Fall MTM Conferences in 1976 and at the Spring MTM Conference in 1977.

Articles on work measurement and the military standard, which appear in Industrial Engineer, The Defense Management Journal, and the MTM Journal.

AFCMD membership in the MTM Association.

A program for MTM training and certification of certain industrial engineers who are resident at Air Force Plant Representative Offices.

After revisions and continued dialog with industry and professional association people, but without their complete agreement, MIL-STD-1567 (USAF), Work Measurement, was published with the date of 30 June 1975. (10) The requirement for use of and references to a DOD Data Bank were deleted. The requirement for government data rights to standards developed in response to the military standard was also deleted. Additional compromises were made in the areas of coverage and accuracy.

The standard was developed to apply to major Air Force weapon system production contracts -- those of $20 million annually or $100 million total. It was also developed to apply to a full-scale development contract of $100 million or more that was to precede such a major Air Force weapon system contract. Construction, facilities, off-the-shelf commodity, time and materials, research, study, and development contracts other than those preceding a major production contract were excluded. (10) The standard does not become effective, of course, until incorporated into contract.

The intent of the applicability provision was, of course, to limit the application of the standard to those instances where it would be clearly beneficial.

The standard is also applicable through flow-down to certain subcontracts; though flow-down may be waived. (10)

The general requirements of the standard are:

"a. A work measurement plan and supporting procedures.

"b. A clear designation of the organization and personnel responsibility for the execution of the system.

"c. A plan to establish and maintain engineered labor standards of known accuracy.

"d. A plan of continued improved work methods in connection with the established labor standard.

"e. A defined plan for the use of labor standards as an input to budgeting, estimating, production planning, and 'touch labor' performance evaluation." (10)

The intent is simply for the contractor to have a documented, disciplined, integrated work measurement system.

Certain specific requirements of the standard will be highlighted below. The first of these is for Type I standards to "be backed up by sufficient data to statistically support an accuracy of ±25%, with at least a 90% confidence level." (10) This represents a significant compromise from the original position of ±10% with a 95% confidence.

Why an accuracy requirement of ±25% with a 90% confidence level? This is, in fact, a maximum compromise position. The requirement is a minimum common denominator that should be exceeded when warranted. Industry resistance to the accuracy requirement resulted in revision downward of earlier proposed requirement to the 90% ± 25% level. There is still some industry suggestion that 90% ± 25% as a common denominator is excessively stringent. This appears to be somewhat irrational. Most standards routinely exceed the 90% ± 25% requirement. Most standards in commercial industries without incentives probably exceed 95% ± 10%. Using time studies, 35-1/2 times fewer observations are needed to demonstrate 90% ± 25% as to demonstrate 95% ± 5%. (11) The appropriate MTM techniques normally result in an accuracy of 95% ± 5%.

There is also a requirement for the contractor to "develop and implement a Work Measurement Coverage Plan which provides a time-phased

schedule for achieving 80% coverage of all categories of touch labor by Type I standards." Furthermore, this plan "shall be based on cost trade-off analyses which relate savings to be accrued through improved productivity and simplification of work methods to the cost of attaining Type I standards coverage." (10)

Why 80% coverage? There are three reasons. The first is that according to the Pareto Distribution or ABC Curves, we could expect 20% of the time standards to cover 80% of the direct labor hours. The second is that about 80% coverage of the direct labor hours appears to be a reasonable minimum to give credibility to and promote confidence in a work measurement program. The third reason is that 20% of non-coverage should provide sufficient flexibility by a reasonable margin to accommodate the true anomalies that may not justify engineered time standards. When one looks at the coverage achieved in the commercial market, 20% of non-coverage seems indefensibly high. However, the 80% coverage requirement seems a reasonable compromise from the original 90% coverage requirement.

The subject of realization factors and their use is complex, and some discussion is needed to understand the military standard requirement in that area.

Simply stated, standards are often adjusted by a variety of factors for a variety of uses for a variety of reasons. The result of this process can promote or denigrate effectiveness. If, for example, one estimates using standards modified by a realization factor based on experience, then the standards can become irrelevant. Philosophically (but not mathematically), this can be expressed by:

$$\text{Estimates} = \text{Standards} \times \text{Realization Factor} = \text{Standards} \times \frac{\text{Actuals}}{\text{Standards}} = \text{Actuals}.$$

or

$$\text{ESTIMATES} = \text{ACTUALS}$$

In other cases, for performance measurement, targets are created by assuming standards will be achieved (100% efficiency) at specific unit of production, say 1000. Thus, as discussed earlier, the performance target for Unit 1 on a 84% curve would be 5.7 times the standard. In some systems, even these targets are adjusted further on the basis of past performance to targets. If one allocates and controls the budget based on these targets, then managing to budget provides little incentive for efficiency. (12). When standards provide the basis for determining

schedules, shop loads, and manpower levels; some factoring may be necessary to provide realism. Performance, absentee rates, and other considerations must be made. In these instances, the use of realization factors is beneficial. The military standard requires: "when labor standards have been modified by realization factors, each element which contributed to the total factor shall be identified. The analysis supporting each element will be available to the Government for review." (10)

The purpose is to assure that such factors are correctly used in estimating. Estimates should not condone or perpetuate past inefficiencies. Simply, we wish to inhibit inflated estimates. We want the estimates to standards to compare favorably with the budget targets so that managing to budget can better promote efficiency.

The military standard recognizes that manufacturing labor performs to expectations. When history with all of its attendant inefficiencies forms the basis of estimates, these estimates when priced influence the budget. Of course, the learning curve and realization factor must also be considered when setting planned time targets for touch labor performance on the factory floor. What results then is a target which can be as much as 25 times greater than the time actually required to perform a given task. Thus, if an employee is given 50 minutes to do a task which "should take" two minutes, peer pressure alone will dictate that he consume the allotted time. Unfortunately, these targets, to the extent that they are so perceived, become the expectations to which manufacturing labor performs, and the cycle is self-perpetuating.

When standards provide the basis for estimates, then inefficiencies must be so identified. When standards similarly provide the expectations for performance, unreasonably poor performance can be less comfortably tolerated. Thus, the military standard works through both labor performance control and budgetary control mechanisms to help assure the expectations that determine performance are reasonable and represent reasonable efficiency.

The military standard requires an audit at least yearly. The exact requirement is:

"The contractor shall use an internal review process to monitor the work measurement system. This process shall be so designed that weaknesses or failures of the system are identified and brought to the attention of management to enable timely corrective action. Written

procedures will describe the audit techniques to be used in evaluating system compliance." (10)

Why an audit requirement? In short, to help assure system discipline. We, the Government, are not asking to audit the contractor. We are asking him, the contractor, to review himself. We view audit as the key to system discipline. I have heard others outside the Air Force express the same opinion. Audit is the key to confidence in the system and the time standards. Demonstrating accuracy and coverage is important, not so much for the Air Force as for the contractor. If the contractor's work force doesn't believe in the standards, the value of those standards will be largely lost.

The audit is required by the MIL-STD to be of specified scope. That scope includes all of the aspects of the work measurement system we thought management should be concerned about: accuracy of standards; validity of methods, coverage; effectiveness of standards used in planning, estimating, budgeting, and scheduling; timeliness, accuracy, and traceability of production count reporting; accuracy of performance reports; reasonableness of efficiency goals; and the effectiveness of corrective actions resulting from variance analyses.

We required that the audit reports be available for Government review. How else, how less painfully for the contractor could the Government assess the discipline of the contractor's work measurement system? Though we have left the details of the audit to the contractor, we have demonstrated to our own satisfaction that employing a technique such as sequential sampling makes auditing coverage and accuracy quite practical and economical.

Need

With the publication of MIL-STD-1567(USAF), three new needs arose. First, the MIL-STD needed to be incorporated into a weapon system contract. The MIL-STD is effective -- that is, is a requirement -- only after it has been incorporated into a contract. At this point in time, we had devoted an enormous effort, the result of which was a tool. No benefits had accrued or would accrue until the tool was used -- until MIL-STD-1567(USAF) was placed on contract.

That no benefits had yet accrued was really not true in one sense. That sense is that there was an increased awareness on the part of industry that the Air Force was becoming significantly more serious and more effective in advocating MIL-STD-1567(USAF). This alone helped to influence at least one contractor to revitalize his work measurement system consistent with MIL-STD-1567(USAF). Other contractors appeared

to develop a greater and more constructive awareness of their own productivity and of their own work measurement systems. However, this "benefit" could not be taken for granted and was ultimately dependent on the successful contractual implementation of MIL-STD-1567(USAF).

The second need was to successfully administer a contract once MIL-STD-1567(USAF) was so incorporated.

The third need was to document or to be able to document that the administration was successful -- to calculate the actual savings achieved.

Research

In order to incorporate the standard into a contract, we had to be able to demonstrate to the system program offices that such a contractual change would be beneficial. We looked for every example we could find to demonstrate that disciplined work measurement systems provide significant savings and significant return on investment. Several of these examples have been documented as AFCMD Lessons Learned. (14) we prepared a full eight-hour indoctrination briefing which was given to the Aeronautical Systems Division and is scheduled to be given to the Electronic Systems Division and to the Armament Development Test Center.

We worked with AMETA to develop an intensive two-week course in evaluating contractor work measurement systems, which is oriented toward administering the requirements of MIL-STD-1567(USAF).

We developed a methodology for calculating savings attributable to MIL-STD-1567(USAF). If an adequate baseline (current performance to standards) exists, then improvement in labor performance can be dollarized to establish gross savings. The net savings are calculated by subtracting the increased costs attributable to additional work measurement and methods personnel.

If the baseline itself is adjusted -- that is, if the standards or targets against which performance was measured were changed -- then corresponding adjustments would be made to the gross savings to reflect the baseline changes. If no reasonable baseline existed, work sampling would be used to develop an estimated baseline. (15)

Implementation Efforts

We continued our public relations and educational campaign. We worked individually with program offices as well as conducting general indoctrination

efforts. We also worked individually with contractor personnel. These efforts generally provided a basis for mutual understanding and progress and helped to resolve or avert unnecessary standoffs based on purely adversary postures.

We tried to develop public and professional support by working closely with professional associations such as the AIIE and the MTM Association. These associations could not advocate MIL-STD-1567(USAF) on a partisan basis, of course. They did, however, provide excellent forums to discuss and explore the issues in a public and professional manner.

Peer pressure and criticism is a powerful force. By subjecting our reasoning and that of industry and certain contractors to that type of scrutiny, the natural refereeing rapidly invalidated superficial and specious arguments. Acceptance or perceived acceptance of certain Air Force position statements in that arena provided material for others to use in advocating MIL-STD-1567(USAF). Thus we extended the number of effective supporters. As the success of MIL-STD-1567(USAF) appeared more certain, more Air Force advocates appeared. Their espousal of MIL-STD-1567(USAF) helped to better assure the success, for which they could appropriately claim credit. Without developing depth and breadth of support, few researchers appear to be successful in implementing research that is originally resisted or considered controversial. Those that understand and espouse the implementation of research deserve co-credit with the researchers for successes achieved.

We worked with AFSC to develop guidelines for applying MIL-STD-1567 (USAF) to existing contracts. (16)(17) We also are developing more specific guidelines for our administrative personnel in the contractor plants. A new chapter to AFCMD Manual 84-1, Manufacturing Operations, containing these guidelines should be published in the near future.

We insured that industrial engineers from our Air Force Plant Representative Offices and other affected personnel attended the four special offerings of the AMETA Evaluation of Contractor Work Measurement System Evaluation Course. We established MTM-1 certification training for our personnel so that they could be demonstrably proficient applicators of the world's most widely accepted predetermined standard time system.

How the Savings Are Achieved

Before discussing the results to date, some additional background information on exactly how work measurement and methods engineering creates savings is in order.

One key to the savings created by a disciplined work measurement system is methods. Applying engineered standards to operations specifies directly or indirectly how the operations should be done. Setting standards establishes methods. Right from the start, certain efficiencies are engineered in and certain inefficiencies are engineered out.

Engineered time standards provide insurance in two ways. First, they help assure that someone has figured out how to make whatever it is that needs to be made. Second, they help assure that if the method selected does not work well, this will be identified early. In both instances, the insurance is provided by the original baseline -- both the methods and times specified. It is sometimes argued that the original baseline is unimportant so long as improvement is measured to it. Experience has shown that it is more true that if the baseline is too high, it is impossible to recover no matter how fast one improves.

Two large commercial aircraft projects were claimed to have sustained a fantastic rate of improvement or learning. This suggests that the aircraft were produced before someone really figured out how to build them. Both these aircraft programs and their producers experienced some financial difficulty attributable, in part, to the costs of producing the aircraft. Setting standards sets performance targets. Just the act of setting targets improves performance — or so researchers would have us believe. Of course, the more accurate the targets, the greater the confidence of the workers in their realism, the better the performance. Standards can often provide a basis for estimates of greater realism and confidence than other methods. More reliable estimates mean budget targets more directly related to performance targets. Managing to budget then becomes more meaningful in terms of a tool to improve performance. (12)

The analysis of variances of performance to standards helps focus management attention on those problems of greatest significance. Supervision, methods improvement, and other actions can then address those problems to improve performance. Once again, methods appear. By applying the discipline of methods improvement to those operations identified as most needing attention, improvement becomes routine.

An audit program disciplines the system. This assures that when methods are used other than those on which the standard is based, one of two things happens. In one case the method is less efficient than that on which the standard is based; the standard method is enforced. In the other case the method is more efficient; the standard and job instructions are revised to capture the improvements.

There are, of course, many other benefits which result from a disciplined work measurement system. In the areas of planning, scheduling, loading, and manpower forecasting; knowing how long the work should take is invaluable. Without this information to some reasonable degree of accuracy, several undesirable things often happen. In one case, the estimates are overly conservative. Too many people have too much time to do too little. That not only costs too much, it erodes the ability to perform and to control performance. Taking the time allowed, or in the "Parkinsonian" sense; permitting the work to expand to fill the time available, (13) establishes new and expensive norms of acceptable performance. Estimates for future efforts based on the history thus created compound the problem.

Sometimes, inefficiency is created by too many assigned to do a set of tasks and getting in each other's way. In certain cases, this causes the contractor to fall behind schedule. Ironically, the common response of putting more people on the job often exacerbates the problem. Once again, the methods approach integral to work measurement would both help avoid the situation in the first place and result in reducing people getting in each other's way in the second place.

The use of engineered standards of known accuracy to establish performance expectations increases the reliability of those expectations. Such standards are recognized by both management and labor as representing reasonably attainable performance with reasonable efficiency. This narrows the range of performance that can be comfortably tolerated by both management and labor. The end result is productivity improvement and a better chance of meeting schedules.

In another case, schedule targets may be unintentionally inadequate. This can set up a chain of actions. Normally some precautionary pad is included, this pad is then removed a step at a time. In some cases, however, by the time it is discovered that the pad was inadequate in the first place, it is often too late to take the corrective actions that would have been most effective.

One should not infer that work measurement is a panacea. It is, however, a proven, established technique. A disciplined work measurement program is the heart of effective work planning and control. Work planning and control can be effective without work measurement and can be ineffective with work measurement; however, experience shows the opposite is overwhelmingly more often the case.

One other key to savings should also be discussed. That key is discipline. Most of the savings in the aerospace industry will come not so much from

developing completely new work measurement systems, but from disciplining or revitalizing existing systems.

The military standard is a management tool which says, in essence, we the Government have been generally disappointed with the self-discipline contractors have exercised so far. We expect more. We deserve better. We are going to require it.

We have noted that as our expectations are raised, the contractors tend to raise their expectations. It is truly the increased contractor expectations and discipline that create the savings. The results which I will describe shortly did not require entirely new work measurement systems to be created.

The billion dollar savings potential originally envisioned was based on a dollarized, twenty percent improvement in direct labor productivity spread across Air Force contracts. Since that time, some more precise and more supportable calculations reinforce the billion dollar savings potential in another manner.

The base against which MIL-STD-1567(USAF) was designed to apply was major ($100 million or more) Air Force full-scale development and production contracts. The face value of major AFSC contracts is about $38 billion. Of these major contracts, the vast majority are for production or full-scale development efforts, certainly $25 billion or more.

Of this $25 billion, more than 30% represents the burdened value of direct manufacturing. Positive influence on at least two-thirds of this direct manufacturing effort seems feasible. A twenty percent savings or improvement potential still appears reasonable. This would create a savings of ($25B x .20 x .20) -- at least $1 billion. Realistically, the savings potential should be significantly larger.

In addition, about 40% of the face values are used for procurement. About a five percent savings should be made in these expenditures. The reason for those savings are the flow down of increased expectation and discipline. As the contractor disciplines his own work measurement system, he will expect more and be able to more accurately determine what manufacturing should cost. This will result in his improving his pricing ability with his subcontractors and suppliers. In addition, as the value of MIL-STD-1567(USAF) is impressed upon the primes, the primes may choose to flow down the requirement to their subcontractors.

This 5% savings, which is somewhat understated, would total ($25B x.40 x.05) -- an additional $1/2 billion.

Results to Date

To date, MIL-STD-1567(USAF), or a modified version, has been incorporated into four contracts. These are the B-1 Airframe contract, the B-1 Avionics contract, and the two 30mm Ammunition contracts in support of the A-10 Program.

At one contractor's facility, $6 million in savings associated with voluntary compliance were achieved in 1976. Savings, of course, continue to accrue.

Voluntary efforts to improve or enhance existing work measurement systems, sparked by MIL-STD-1567(USAF), are resulting in improved productivity and corresponding savings at several additional contractors.

Incorporation of the MIL-STD-1567(USAF) or modified versions of the standard are likely for several additional contracts in the near future.

The total savings achieved to date approximate $10 million or about 1% of the billion dollar potential. However, these savings, the research, and the implementation efforts demonstrate that the billion dollar potential exists — AND that with perseverence, it can be realized.

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$$N' = \left(\frac{Z}{S}\right)^2 \frac{[N\sum x^2 - (\sum x)^2]}{(\sum x)^2}$$

where:

N' = Number of readings required.

N = Number of readings taken in the sample.

Z = The number of standard deviations required based upon the confidence level established by management.

S = Percent accuracy (expressed as a decimal) required as established by management.

x = Each elemental time value.

For 95 ± 5 Z = 1.960 S = .05
For 90 ± 25 Z = 1.645 S = .25

The ratio of N' 95 ± 5 to N' 90 ± 25 is 35.49.

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(14) AFCMDP 8-1, 30 June 1977, PD-5.

(15) AFCMD/PD Ltr, AFSC Five Year Manufacturing Advancement Plan, 29 December 1976, to AFSC/PPD

(16) AFCMD/PD Ltr, Guidelines for Applying MIL-STD-1567(USAF) to Mature Programs, 8 March 1977.

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INDUSTRIAL PROCUREMENT RESEARCH: USES AND EXPECTATIONS

DEFENSE SYSTEMS ACQUISITION

Working Toward Improving the Process

John H. Richardson
Executive Vice President
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Speaking for myself and for the gentlemen accompanying me on this platform, we appreciate very much the opportunity to contribute some of industry's views and perceptions to this symposium. Since military procurement inherently involves DoD contracting with industry, the translation of procurement research into action is necessarily a joint concern of both DoD and industry. My colleagues and I will be looking at a number of facets of the military procurement process where improvements are being made or innovations are being tried.

I will start off with a summary of several systems acquisition problem areas in which joint attention by the services and industry is yielding some real progress. Tom Pownall, Executive Vice President of the Martin-Marietta Corporation, will then talk about the particular area of R&D acquisition. Finally, Harry Gray, Chairman and President of UTC, will describe some of the tangible results of procurement research as seen in the UTTAS program.

There are a number of channels through which military and industry managers have worked together on acquisition issues. For example, there was DARCOM's Atlanta IV last month. The Atlanta meetings have stimulated face-to-face discussions on the acquisition process between senior Army management people and their counterparts in industry, and have been an outstanding success.

Then there are the industry association and professional society workshops, symposia, and seminars that concentrate on specialized phases of the acquisition process.

And this year this annual DoD Procurement Research Symposium includes industry as well as government presentations.

I am going to concentrate on a particular series of events---instigated by the military---which have created a healthy climate for yet another approach to improving systems acquisition. I refer to a series of small top level "tell it like it is" meetings through which significant problems have been identified and acted upon. These meetings got started back in mid-1975, when General Samuel C. Phillips, then commander of AFSC, wrote:

"The Air Force Systems Command wants to explore ways of improving the acquisition process and strengthening understanding between AFSC and our prime contractors... The objective is to provide a two-way flow of communication which cultivates a 'tell it like it is' environment, focusing on the major issues in the acquisition process.

"There is no formal agenda. All discussions are on a non-attribution basis, and the size of each group is limited to one representative from each of four contractors."

Six months later, General William J. Evans, who by then had assumed command of AFSC, gave his whole-hearted endorsement to continuation of the program. And last October, General John R. Deane, Jr., Commander of the Army Materiel Development and Readiness Command, issued a similar invitation.

These "tell it like it is" meetings have been taking place over the past couple of years now. It is my assessment, and I believe that of other representatives of industry who have taken part in them, that these meetings have served a useful purpose---things have been accomplished as a result of them. Here is a summary of some of the problems identified and discussed, together with the actions taken by Air Force and Army management. We'll look at them one by one.

BEST AND FINAL

Problem

The Best and Final Offer (BAFO) technique results in technical transfusion, buy-ins, and auctioneering.

Air Force Action

AFSC directives have been published which prohibit repeated calls for BAFO's.

Representative procurements being identified at SAMSO, ASD, and ESD, are to be negotiated without use of parallel negotiations, e. g., negotiate only with selected source.

Cost realism will be stressed in regulations and during procurement conferences so as to encourage the finding of non-responsiveness to unrealistically low bids.

Army Action

General Deane recently reiterated his concern with Best and Final procedures to the Under Secretary: He has recommended General Officer level, by name, approval for more than an initial request for a Best and Final Offer. Additionally, DARCOM Headquarters must be advised of any repetitive use in procurements of $100,000 or more; and, the use of the ASD (I&L) approved new four-step procedure is now encouraged.

COST-TYPE CONTRACT WITH CEILING

Problem

The use of cost-type contracts with ceilings is not desirable since such contracts entail the risk associated with a fixed price contract, but have all the controls inherent in cost-type contracts.

Air Force Action

Headquarters AFSC conducted a survey of field offices to determine the extent to which this contracting technique was being used. Initial results indicated a need for specific policy formulation in this area. Policy implementation is being studied.

Army Action

The Army also conducted a survey of use of this contracting technique, and as a result developed and transmitted a new policy to field activities. This policy indicates that not-to-exceed ceilings will not be included in new cost-type contracts or through modifications of existing cost-type contracts except in unusual circumstances. All proposals to include such ceilings must be referred to Headquarters DARCOM for review.

TAILORING

Problem

Over-application of "specs and standards" results in unnecessary costs. There is need to provide contractors greater flexibility to offer cost/performance trades.

Air Force Action

Draft RFP's are being utilized to obtain industry input prior to finalization of RFP, and RFP clauses (including incentive provisions) have been developed to encourage contractor comments in proposals.

Handbooks covering selection, tailoring, and application of specifications have been distributed to SPO personnel in SAMSO (GB-1) and at Dayton (ASDP 800-1), and the Air Force Institute of Technology has developed a video tape training film on tailoring. A large-scale in-house educational effort is being undertaken through formal course creation as well as on-the-job training to encourage wider use of commercial standards.

Army Action

MICOM has released a policy letter (700-3) and a regulation (1-36) requiring that certain specs and standards be tailored, reviewed, and approved prior to application on RFPs and contracts.

The Program Management Course at Ft Belvoir has been expanded to include specification and standard tailoring and application of specs and standards in the System X simulation exercise.

And provisions have been made for a two-week course in military specification and standard management, open to both military and industry personnel, at the Army Logistics Management School at Ft Lee.

That's a lot of action, but just to show you that it's tough to win them all, here are a couple of areas that haven't been moving forward rapidly. First, let's look at...

CMSEP (CONTRACTOR MANAGEMENT SYSTEM EVALUATION PROGRAM)

Problem

In normal situations, full application of CMSEP entails much cost-ineffective detail. At least at those facilities where there is a large amount of commercial work, or when a contractor is performing well, the application of CMSEP should be reduced or eliminated.

Air Force Action

An Air Force letter in January 1976 stated: "A review of this area indicates that CMSEP is intended to be a self-tailoring evaluation tool and that the configuration and breadth of a contractor's management system, as it applies to Government programs, determines the degree to which CMSEP is applied. AFCMD controls CMSEP implementation by using a checklist during normal staff visits and holds quarterly reviews of AFPRO operations. In addition, team audits of AFPRO implementation of CMSEP will begin on 26 February 1976." So far, however, we in industry have seen no appreciable change in the application of CMSEP.

Then there is...

CONTRACTOR PAST PERFORMANCE

Problem

The services do not really take into account a contractor's past performance in the source-selection process. We believe that they could and should.

Army Action

On this problem, General Deane indicated in January of this year that he saw no practical path to improvement: "The OSD study group on Profit '76 considered the use of past performance as an evaluation factor and couldn't get anywhere. The concept is unbelievably difficult to implement and there does not appear to be any ready formal solution."

Now let's get back to the positive side where things are really happening.

VALUE ENGINEERING

Problem

There is much interest in the Value Engineering Program at the higher management levels in the Air Force, but at the working level there is considerable lethargy.

Air Force Action

In 1976, AFSC issued a regulation requiring the setting of VE goals, a plan for achieving them, and regular status reports to AFSC Headquarters on all major programs.

In October 1976, a V. E. workshop was conducted with the AFSC Division staff value engineers to assess problems and to structure a positive V. E. enhancement program. In January of 1977, AFSC sponsored a "V. E. Congress", with participants from AFSC System Project Offices, Air Force Plant Representative Offices, other DoD organizations and contractors.

AFSC has scheduled top-level briefings this spring for all subordinate commands. The briefings will outline the VE program, describe its advantages, and request commitment to achieve results. In addition, the Air Force Institute of Technology is conducting VE training programs for management and contracts people at all commands.

Incidentally, several changes are in the process of being made to the Armed Services Procurement Regulations VE sections, which should reduce their complexity, clear up the language, and encourage broader application by DoD agencies and industry.

C/SCSC (COST/SCHEDULE CONTROL SYSTEMS CRITERIA)

Problem

The need for C/SCSC on mature programs should be reviewed. After several years of a production program, the cost effectiveness of C/SCSC is questionable.

Air Force Action

Headquarters AFSC determined that re-evaluating and appropriately modifying cost reporting requirements as a program matures, has merit. AFSC product division procurement organizations were advised of the need for program offices to continually review the stability/maturity of their programs and to "tailor" cost performance reporting requirements accordingly.

Tri-Service Action

Three months ago, industry received a letter from the Tri-Service Performance Measurement Joint Executive Group which said, in part: " The purpose of this letter is to request the recommendations of your firm regarding possible improvements in the application of C/SCSC to the management control of production contracts. The PMJEG is considering the development of a modified C/SCSC interpretation exclusively for production contracts. It is also contemplated that a committee representing contractors will be organized to work with the PMJEG in this effort."

Now in addition to the problems I have just touched on, there are of course many other areas in which improvement or innovation is called for. Here, for example, are three subjects that have not yet received a thorough airing at our joint meetings, and that we shall be discussing at future sessions:

Planning Purpose Prices for Interesting Options

Buyers, RFP writers, and program managers should be stopped from asking for "what-if" prices for options that may be, but are not now, a part of the program to be priced in a source selection. Such a process, if permitted, inescapably leads to "liar's poker."

Front-end Loading to Reduce Life Cycle Costs

Much has been said about paying more for initial acquisition if it will save support costs in the out years. These support costs used to account for less than 50 per cent of total life cycle costs. That figure is now up to about 65 per cent. The principle of paying now to save later makes sense, but does DoD really mean it and how can we implement the principle?

Funding Competitive Prototyping

I am the first to agree that the Government has really been getting more than its money's worth from competitive prototyping. I also agree that DoD has become quite proficient at estimating. However, we ought to be able to recognize on the basis of experience that it is not in the best interest of DoD or industry to place a contractor in a position of great financial risk, and that is what these underfunded prototype programs do. If we are going to continue with competitive prototyping, reasonable funding levels should be provided to the contractor participants.

In summary, I have presented some concrete examples of how industry and government <u>are</u> working---hard and together--- to improve our understanding of each other's problems and to improve the acquisition process. Significant things <u>have</u> been accomplished; genuine progress is being made. Procurement research <u>is</u> being translated into action.

RESEARCH AND DEVELOPMENT AQUISITION

Thomas G. Pownall
Executive Vice President
Martin Marietta Corporation

Good afternoon Ladies and Gentlemen.

What I do intend to talk to you about is two or three R&D elements and how they relate to the A105 circular about independent research and development. That last subject is very near and dear to all of us on this panel and all of us in industry.

Research and Development consists basically of the technology base and enhancement, which is simply the early pursuit of ideas, concepts and facts, and the full scale development programs. The first part accounts for a couple of billion dollars of the total RDT&E, but it's composed of about 20,000 separate efforts and that's a very substantial number. It would be substantially larger and a good deal less managable were it not for the independent research and development effort about which I will speak more fully. The full scale developments account for about 8 billion or 70% of the overall RDT&E effort. In this area, significant changes in the major systems acquisition process will be occuring as a result of OMB circular A109, which incorporates several recommendations of the Commission of Government Procurement.

There will be an impact on R&D acquisition also. Following the Agency Head's approval of a Mission Need Statement, industry is to be solicitated for it's ideas of system designs concepts that satisfy the mission need. What is being attempted here is to start from a general area, and work all the way through the system, to arrive at a matching of that need with some hardware, system or at least, an answer. I believe that is an attractive proposition. The solicitation is to explain the need in mission or capability terms, not equipment terms, and it is to give schedule objectives, constraints and program objectives. This contrasts sharply with the traditional practice of delineating a major system in explicit terms and soliciting industry for the conduct of the R&D to evolve the specific system described. A109 enables contractors to be free to propose their own technical approach, main design features, sub-systems, alternatives to schedule, cost and even capability goal. Competitive parallel short-term contracts are to be used to fund well defined activities during exploration of system design and concept alternatives. The superior concepts are then to be funded for competitive demonstration, and from these demonstrations, winners will be selected for full scale development and potentially, the initial production.

What are the implications for industry? For industry, there will be a very considerable emphasis on the front end of the procurement process with the attendent requirements to explore innovative concepts addressing customer needs. This in turn will require that industry devote more of its independent research and development, the IR&D piece, to the exploration of concept and feasibility study.

IR&D is broadly defined as that R&D not required by a contract or a grant. The major defense contractors negotiate annual agreements with the DOD based on submission of extensive technical plans describing in detail the IR&D they intend to conduct during the year.

These annual agreements define a dollar ceiling representing the maximum amount of a contractor's IR&D program that DOD will accept. Almost everybody in industry spends well over that ceiling allocation, and it can vary from a few percentage points to maybe as much as 30 or 40% depending upon the level of activity of which they're engaged. We can't control that because we might be very active in one six month period, and maybe not very active in the next six months. Or we may be very active for a two year period, and not very active for a one year period. So we've got to do what we've got to do when we've got to do it, whether the money has been provided as a piece of the IR&D allocation or not.

Dr. Curry, who is no longer in Government, described IR&D this way. He said the Department of Defense is committed to competition for its selection of suppliers. This policy obviously involves the cost of enabling a sufficient number of suppliers to qualify themselves to compete for our business. The effort a contractor puts into qualifying himself is called Independent Research and Development. He said our reasons for accepting this cost are based on the conviction that the returns of competition are immensely greater than the expenditure it involves. Competition lowers the direct cost of our requisitions. He said that the tasks that add up to the supplier's cost of qualifying himself for competition are internally defined by the supplier. Directions from DOD that classify tasks for supplier cost would only turn competition into directed procurement. Finally, he went on to say that the concept of independence is an inherent feature of any contractor's IR&D. Successful competition (being in business) is based on the capabilities one will possess and can apply at each competitive point.

Only the individual company is accountable for the decision as to how and where its own competitive capabilities must be sustained. This is the area in which management must use its very best judgement because funds ill spent in the independent area will absolutely push it out of business. If they're spent properly, then whether or not we gain the business, we are at least competitive in the right area and we have an opportunity to offer ourselves as reasonable and decent competitors. Otherwise we become nobodies and shortly after that we just disappear from the scene.

What is the impact of A109 on IR&D? Well the longer term affect of A109 will be a shift in the reflective proportions of a contractor's conceptual studies, research and development categories, which make up his IR&D program. This differs with the highly optimistic view of one witness to the Congressional Hearing on IR&D in Sept 75 who ventured the opinion that A109 type procedures would eliminate the D element of IR&D and thus result in a reduction of 90% in IR&D costs. Well it would be absolutely delightful if it were true but it's not. As I mentioned earlier, we spend substantial amounts of our money, and we don't make any money on it. There is no money to be made, fundamentally, in the R&D area. As a matter of fact, a year or so ago the Aerospace Industry profit was about three and one half percent. That's a big number if you multiply that by some billions of dollars, but it's not big on individual contracts by any means. However, application of A109 principals account for substantial reductions in the B&P cost which are handled by DOD in a manner similar to the IR&D cost.

For the full benefit implicit in A109 to be realized, all the players, from Congress and the Agency, must sincerely embrace the concept and not attempt to superimpose it upon the traditional method of major system acquisition. The Navy Ship 1 Intermediate Combat System, Certs, is the major defense tactical system to follow A109 procedures. It is experiencing some difficulty with Congress, which seems bent on supplying a specifically identified light-weight fire control system. This is not to suggest that the one that is being proposed isn't the answer; it's just that it's probably not the only one. To quote a recent editorial in the Government Executive Magazine, which is produced around Washington and always has a well known government executive on the cover, "industry already feels considerable Pentagon pressure on where to spend its IR&D and B&P, the business proposal piece, discretionary investment funds." A109 increases that pressure by bringing them in

even earlier for conceptual studies. It goes on to say that after doing that, the industry is told the investment is in the trash barrel, and they are to do it all over again using the in-house developed school solution. Industry will flock away from A109 in droves.

That reminds me of an interesting story. This guy was one of the world's worst theater performers, was a substitute in a Hamlet play, and the principal in the play became ill and he came on stage and the audience hated him. He was such a pompous ass that they couldn't stand him. He had been on for twenty or thirty minutes and they began to throw things on the stage, and he was annoyed but he continued on without saying anything and just went on and on and on until he came to the famous soliloquy. He was about halfway through when somebody pasted him with a very ripe tomato right on the side of the head. He stopped and said to these people, "you know, you're being very indecent and I don't understand why you're doing this. After all, you know, I'm only an actor; I did not write this crap."

If that's your view of A109, I don't know, but I would hasten to add that it is not mine. Sometimes, we are all status co-experts. We enjoy doing business the way we used to do business; the same old stand, the same old people. We all change and times change dramatically. If you don't believe that, just look at what's happened in the last ten years. Contract form generally doesn't give us much trouble unless we're losing a lot of money, and you usually hear about it when we are losing money, "It's the wrong kind of contract!" But when we're doing fairly well, we're usually fairly happy. A109, may permit us to exercise our minds and our ingenuity to a considerably larger degree than before. If, in a couple of years, we fall right flat on our faces, we'll have to come back and admit that there were some considerable problems with it. I personally believe that the A109 concept will prevail once the initial roadblocks and problems attendent to the required reorientation of thought and action on the parts of all involved are overcome. Industry, I hope, stands fully prepared, if not eager, to play its part in reducing procurement costs and lead time and looks forward to the vigorous implementation of A109 concepts. Thank you very much.

"UTTAS: TRANSLATING PROCUREMENT RESEARCH INTO ACTION"

Harry J. Gray
Chairman, President and
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United Technologies Corporation

I'm going to continue the themes introduced by John Richardson and Tom Pownall. I would like to tell you about some innovative procurement techniques which emerged from one of our company's major defense programs -- the Utility Tactical Transport Aircraft System, or UTTAS, which our Sikorsky division is producing for the Army. I cannot suggest that all of the requirements placed upon Sikorsky are unmixed blessings. I do believe, however, that the program's structure favors the contractor with the best product and the tightest program control. Since that turned out to be Sikorsky, I'm happily prepared to emphasize the positive.

Procurement research is relatively new -- as a structured discipline -- in the Department of Defense. Many of UTTAS's innovative program management and contracting procedures were developed by people who were actually doing procurement research. They just hadn't been told it had a name. Semantics aside, the selection of the UTTAS program as a topic for discussion makes good sense. The program, with its innovative concepts, was developed by the Army Aviation Systems Command in St. Louis, and it is working well.

My remarks today will cover the program background and request for porposal, the overall program schedule, and some specific features of the development and production contracts.

I will go into some detail, but I understand you are here to discuss in depth the wide spectrum of research subjects covered by the word "procurement." You are not here to listen to broad generalities which you can't zero in on.

Actually, the UTTAS requirement originated before the Vietnam war. At that time Army planners decided that a utility helicopter -- large enough to carry an 11-man infantry squad -- was the key to the developing concept of airmobility. As you veterans of Vietnam know, when fighting escalated over there the Huey helicopter was modified and pressed into service as a troop carrier, even though it could not carry 11 men on a hot day.

The first large-scale helicopter operations in history took place in Vietnam. Lessons were learned and concepts tested. As the shortcomings of existing helicopter designs became apparent, two approaches emerged:

First, requirements for the next generation of helicopters were revised continually to reflect combat experience. Second, in areas where existing technology could not meet these new requirements, research projects were started. Some research was done at government installations, some was performed under contract by industry, and some was conducted independently by industry.

As a result, three manufacturers had the necessary R&D base to respond when the Army issued a request for proposal in 1972. This RFP demanded more than had ever been achieved in a helicopter -- better performance, crashworthiness, reliability, survivability, and ease of maintenance. Sikorsky was selected for one of the two development contracts.

It was no coincidence that the technology was ready. The RFP resulted from years of effective communication between government and industry. The requirements, while demanding, were realistic. The UTTAS request for proposal, in fact, was the most specific ever written for a helicopter.

After years of study contracts, research contracts, symposia, seminars, and technical exchanges, the Department of Defense knew almost as much about what the contractor could and couldn't do as the contractor himself. Research and communication in pre-RFP days were better than in earlier programs. They clearly contributed to the success of the UTTAS program. The excellent RFP which resulted was a milestone in practical procurement research.

So in September of 1972, two manufacturers with long experience in the helicopter business began developing a Utility Tactical Transport. Sikorsky and the Vertol Division of Boeing were each required to turn over their prototypes to the government in slightly more than three years for government competitive testing. This evaluation was not only against each other, but also against the Bell Huey which the winner eventually would replace.

The RFP specified an aircraft that could lift a squad under the most unfavorable temperature and altitude conditions. . .fly it a prescribed distance through enemy small arms fire. . .take extreme evasive maneuvers. . .and, if shot down, protect the occupants from a severe crash. Each component had to achieve unprecedented reliability, and the aircraft had to be maintained under austere conditions.

There were two key constraints on achieving these goals. First, air transportability placed a severe constraint on size. Second, the RFP placed an even tougher constraint on unit airframe cost, something I'll have more to say about later.

In the RFP, each of the desired characteristics was assigned a quantitative target, measured in maintenance manhours per flight hour, mean time between failure, and so forth. There were dozens of characteristics with performance targets. Each was separately achievable as a result of the research performed in the late 1960s.

But were they achievable together, on the same aircraft, within strict weight and cost limits? In fact, they proved to be.

Though the Sikorsky engineering team was challenged to the limit of its skills in meeting these targets -- meet them they did.

The Army is to be complimented on writing an RFP which integrated such a large number of performance targets into a system which could realistically be built.

The Army's overriding goal, of course, was an aircraft technically able to perform its design mission. Almost as important, however, were the needs related to cost, survivability, and readiness. Survivability, by the way, is a word I especially like. Some of my experiences as a young infantry company commander in Europe during World War II gave me an early and abiding appreciation of survivability. I even like the sound of the word.

As an example of how it relates to UTTAS, consider just one of the requirements -- that UTTAS be able to survive a 42-foot-per-second vertical crash without deforming the cabin and crushing the occupants. That is 29 miles an hour straight down! It's a challenging design objective when you consider the weight of the transmission, engines, and accessories mounted atop the cabin. (We were able to meet this objective).

An unscheduled example of meeting system goals occurred last August, during government competitive tests. One of our UTTAS prototypes was flying a night mission with 11 troops when it had to make a forced landing. The aircraft landed vertically, cutting a swath through a dense grove of pine trees with trunks up to six inches in diameter. It came to rest tightly wedged between two of the pines. Between 40 and 50 trees were completely severed. How did we get it out? We replaced the main and tail rotor blades and flew it out the following day. There were no injuries and no structural damage except to the blades. We're proud of that.

How about life-cycle costing? Obviously, the concept did not originate in the UTTAS RFP. But this probably was the first program in which considerations of life-cycle costing penetrated all phases of the design. As a result, improvements in maintainability, reliability, and survivability enable UTTAS to project annual operating costs substantially below those of the Huey, which is a much smaller and less sophisticated aircraft.

I would emphasize that what was <u>not</u> specified in the RFP was almost as important as what <u>was</u> specified. The RFP concentrated mainly on objectives. It avoided specifying methods and techniques. Thus, the two contractors were allowed full <u>flexibility</u> in meeting those objectives.

I think it is fair to say that both contractors responded with ingenious solutions to some design problems. There are many mutual benefits when a contractor has innovative ideas and the government is willing to evaluate them. I would add parenthetically that this is important for you procurement researchers to keep in mind.

Competitive prototyping is ideas for the evaluation of new ideas. The concept of broad design flexibility within the requirements is sound and should be retained as far as we are concerned.

At this point I'd like to share with you my thoughts about competitive prototyping.

The UTTAS Government Competitive Test was a hard-fought competition that brought out the best kind of team effort from Sikorsky. <u>Competition</u>, I repeat, <u>competition</u>, brings ideas and effort out of people that money <u>and time alone</u> cannot generate. Faced with the possibility of losing a competition, a design team will decide <u>not</u> to pursue a dead-end technological path. Reconfiguration of prototypes can happen equally fast.

An example of this occurred in 1975, when Sikorsky decided that the intermediate and tail gearboxes of the UTTAS should be switched from grease to oil lubrication. Now this is a major design change, requiring the development of oil flow patterns and lubrication lines. Nine days later, the gearboxes had been reconfigured, tested for 50 hours, and were operating in the ground test vehicle. And most of the work was done over Labor Day weekend!

I don't mean to suggest that all new systems should involve competitive prototyping. As you procurement people know, there are times when a sole-source product improvement program is the best and least costly course. A new technological step, however, should involve a head-to-head test of prototypes. There is no doubt that UTTAS represented just such a technological step.

Now let's turn from the RFP to the overall program schedule. There were a number of distinctive features in this schedule. First, there was a fairly long time between award of the prototype contract and award of the production contract. Compared to the development phases of two other competitive prototype programs, UTTAS was about a year and a half longer than the F-16 and roughly twice as long as the A-10.

The extra time was well used in the UTTAS program. As problems arose, we could cope with them. Accordingly, when the production contract was awarded last December, the Sikorsky entry was "production ready."

Another part of the schedule has special interest. This is producibility engineering and planning, which began 16 months before contract award for both contractors.

During the basic engineering development phase, it became apparent that the 20 months between production contract award and delivery of the first production aircraft could be a problem. So the Army decided to fund both contractors to begin pre-production planning prior to the award of a production contract. This was very helpful. It came about a year before the production proposal was submitted. It enabled us to study producibility considerations and facilities planning in detail when making configuration decisions and in preparing our production proposal.

Although the intent was to protect the production schedule by identifying and initiating planning and procurement actions, there was another benefit as well; we had the time to develop a number of innovative production techniques that will definitely contribute to cost control.

Undoubtedly, the modest cost of double funding this relatively inexpensive production planning was money well invested.

Now, to conclude, I'm going to discuss some innovative features of the development and production contracts.

Because of a rigid airframe cost target of $600,000 (in 1972 dollars), we were required as never before to track system cost as a design parameter in real time. So we created a multi-discipline team with the task of tracking the cost of each item on the aircraft with a work breakdown structure number.

This meant setting cost targets, measuring the impact of design and process changes on each component, and keeping track of our status in meeting the overall cost target. In UTTAS, the costs of more than 11,000 individual parts had to be tracked. The discipline and procedures this created were successful in controlling and reducing program cost.

The concept of specifying a result -- or a design-to-cost target -- and allowing the contractor maximum flexibility in how he achieves it, enabled us to develop an effective system to track, control, and reduce cost. We wholeheartedly endorse it. But, since actual costs are sensitive to changes in the production schedule,

allowances should be made for such changes, as well as for government-directed changes in the requirements, specifications, or design.

The Gross National Product implicit deflator doesn't accurately reflect industry costs. I am convinced that price indices more closely reflecting aerospace industry costs would be better for design-to-cost escalation adjustments. Changes in the government business base also impose costs outside a contractor's control. So appropriate allowances should be made. I suggest that some of your research efforts be directed to this subject.

The production contract also contains some interesting warranties and incentive clauses. I understand these items have been subjects for procurement research by the Department of Defense.

Sikorsky has guaranteed hover ceiling, cruise speed, and aircraft empty weight.

Flight tests will be performed by the government on the fifth aircraft of the first production year. The government will weigh all aircraft produced in the first year, and three each year in the succeeding years. Based on these samples, our unit price will be increased or decreased. The total adjustment is the straight sum of the individual adjustments. The adjustment, however, cannot exceed the ceiling price for that year.

The Army also has an option in the production contract to purchase a reliability assurance warranty. Under this option, Sikorsky would be required to perform depot level repair on eleven of the most critical dynamic components on each aircraft for the first three operating years. During this time, Sikorsky is only obligated to repair parts. But Sikorsky can incorporate improvements in manufacture or repair if it chooses. If performance, cost, weight, or other critical attributes are unaffected, Sikorsky needs no Army approval for improved manufacturing techniques.

It is a straightforward system: if the component fails to meet the Mean Time Between Removal Requiring Depot Repair, Sikorsky repairs more components than planned and takes a financial beating. The level of exposure increases up to the ceiling set for that year. Beyond the ceiling Sikorsky bears the <u>full cost</u>. If the components <u>exceed</u> expected Mean Times Between Depot Repair, Sikorsky earns an award.

For items <u>not</u> included under reliability assurance warranty, Sikorsky has to correct deficiencies resulting from defects in design, workmanship, or materials if the deficiency is reported within a specific time after aircraft acceptance. If a defect is discovered, Sikorsky must submit its recommended corrective action within 90 days. Such action is taken at no increase in the contract target or ceiling price.

As far as I'm concerned, incentives and warranties, like competition, are good business. In the case of UTTAS, they were the result of a great deal of bargaining, and I believe they will accomplish their purposes. This is one element of program control which should grow over the next ten years.

The UTTAS program is a milestone in the evolution of procurement research, and it will continue to benefit from innovative program management by Sikorsky and by the Army. So far, the program has been characterized by professional achievements -- an excellent RFP which gave it a good start, a superior design team, and excellent Army management of government competitive testing.

As far as United Technologies and Sikorsky go -- we pledge the Army the best helicopters that have ever flown.

DIMENSIONS AND MODES OF PROCUREMENT RESEARCH

ONE PERSON'S TRAVELS IN PROCUREMENT RESEARCH

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INTRODUCTION

The title of my few selected comments (to establish the perspective of our panel discussion) is a curious title which needs some explanation. Only my wife and children are very interested in my personal travels.

But I have been invited to express a few observations about (i) why I believe managed research is important in the field or procurement; and (ii) what I believe may be susceptible to improvements, based on my personal exposure over the last decade.

I've had several different job descriptions most of which have involved traveling to field procurement offices to conduct inquiries into procurement related problems and to help develop improvements. In a very real way, it has all been a form of procurement research. Therefore, one might say I am one physical example of the concept that procurement research is conducted in differing dimensions and modes. I have had assignments as a contract specialist; a supervisor of a procurement organizational unit; and, a graduate student in the GWU Procurement and Contracting Program where I did research for a thesis.

I've been a member of the Army Procurement Research Office staff, the DARCOM Inspector General staff, and the DA/DARCOM Procurement Management Review staff. Finally, I've been on many ad hoc study teams.

WHY PROCUREMENT RESEARCH?

Where a real need for improvement can be identified, I think we ought to pay the price of procurement research. Why? Well, the need for procurement research is obvious; but General Stansbury has just warned us that: <u>we should not ignore the obvious</u>! So, let me state that "obvious" point a little more explicitly.

As we all know, the vital national defense mission involves both Government and industry; and the critical interface between these two team members is the contract relationship which in turn is achieved by means of the procurement function. And---we accomplish Government procurement by very standardized laws, regulations, policies and operational procedures, by hundreds of procurement offices, thousands of specialists, millions of individual procurement actions, and billions of dollars. The sheer magnitude gives an awesome significance to the work of refining and improving management and performance of the function, even though most of it is accomplished half an inch at a time.

We need to intelligently and diligently promote and support procurement research efforts because there is a very big potential payoff whenever we make a half an inch of progress. That's why!

For example: one of my first research team efforts resulted in a relatively small set of changes to the language of a special provision used by the Electronics Command. Today, thousands of solicitations and contracts effected by this organization routinely utilize the revised language and routinely benefit from the improved contractual relationships. This represents a massive return on the investment in our research.

Similarly, one of the most recent of my personal research team involvements substantially affected the whole procurement program in the Republic of South Korea. It's a fact: successful research pays off handsomely in the US Government procurement business. This logic compels use of the very best of our collective talents and a substantial proportion of our resources.

WHAT TO RESEARCH?

A large portion of our research effort has been concentrated on improving the process of acquiring major weapons systems. Certainly we have needed improvements in this area, and in the last few years we have clearly expanded the state of our art.

But the totality of the procurement program involves much more than just the major weapons systems. As I perceive it, we need to improve our performance of the essential, basic, fundamental steps of the procurement process--the core activities of "blocking and tackling"--as well as to push the state of our art in major weapons systems acquisition. While, in general, we have performed well in the past and are performing well today, we are far from being highly proficient in performance of our procurement function. Many areas are susceptible to improvement.

I have not defined or even outlined an improvement program in my mind. At this state its just a feeling, a "hunch" that I have that we need one. An I'm certainly not blessed with having solutions to the problem trends which I suspect exist. But I do know a couple of things:

First: If we did not continue to diligently maintain our expertise, our local procurement organizations and ultimately our national procurement capability would rapidly deteriorate and we would soon be unable to properly service our customers. If you doubt this, take my word for it. The quality of a procurement shop can slip from excellent to poor in a matter of a year. We must continuously manage our weaknesses and make self improvements where needed.

Second: I also know that we cannot just demand a continued high degree of proficiency and expect to get it. I was reminded of this rather elementary bit of wisdom when I stopped overnight in Tokyo a few months ago on my way to Seoul, Korea. In the desk drawer of the hotel lay a copy of some parables of BUDDA, and I glanced at a few, one of which went about like this:

-- A man felt himself to be fairly rich and wanted a house much the equal to that of his neighbor who had a three story house. The man commissioned a carpenter to build such a house. The carpenter began to build a foundation, a first floor and a second floor, preparatory to building the third floor. The man became angry and terminated the contract. He demanded that all he wanted was the third floor, so that he could display equality with his neighbor. Of course, the carpenter was unable to help.

-- as BUDDA said it:

"A foolish man thinks only of results and is impatient with effort that is necessary to get good results. No good can be attained without proper effort, just as there can be no third story without the foundation and the first and second stories."

Some areas may not be susceptible to improvement by concentrated research efforts, from a practical point of view. But identification of specific areas is certainly one of the first places to start. If I were to be asked, for example by means of a market research questionaire, I would add at least the following entries to the general list:

-- With respect to operational aspects:

- we need to make source selection decisions better and structure the evaluation factors of Section D of our solicitations a little more sensibly -- in both minor as well as major procurement actions.

- we need to better distinguish between term and completion forms of cost-plus-fixed-fee type contracts, and thus better identify what is to be bought and sold via our CPFF contracts.

- of course, Section E still needs improvement. We still have trouble stating what supplies and services we want to buy. We know what a Work Breakdown Structure is, as well as the nature of contract line items and subline items. But we are not universally adept at merging the two concepts in a clear statement of the required supplies and services.

- we need to better conceptualize our requirements and correspondingly our contract schedules in procurements of engineering services, maintenance services, base operation services, facility management services, etc. We need to stop using money as the driving factor, even though that's about the only area wherein we can be very specific. (Every time we do this, all the money that's available tends to get spent.)

- we need to learn how to contract with foreign governments much better than we now do.

- we need to know more about how to cope with widespread, pervasive collusive practices which may well exist in offshore procurement activities--i.e., how to select sources and fix prices in a way whereby we control the decisions.

- we need to improve our techniques of contracting for architect-engineer services.

- we need to learn how to better use Basic Ordering Agreements, particularly in establishing "open end" arrangements with A-E firms and obtaining engineering support to production.

- we need to find ways to expand our use of the award fee concept, and to receive the benefits to be derived from aligning the contractor's and the governments' objectives in an evolving pattern, without making him a personal servant.

- we need to learn how to better utilize exculpatory language in both competitive and noncompetitive production contracts for military design equipment where our technical data packages are inevitably less than perfect. Some organizations are skillful at this technique. Others are not.

-- With respect to performance of management functions:

- we need to know how to better document and transfer lessons learned. For example, we've learned so much in the last few years about flying before buying, milestone contracting, managing change, etc. But I'm afraid much of our experience may have slipped through the cracks and the next person will have to reinvent the wheel.

- we need to improve our issuance of procurement instructions and SOP's at the Chief of the Purchasing Office level. A few years back we made major changes and rendered almost all local guidance invalid, in deference to the ASPR, APP, DARCOM PI's (Army), AFPI, NAVPI, etc., and I think a void now exists at many local offices. Guidance which ought to be published at the local level is not now entirely adequate.

- the role of the HPA and of the contracting officer still needs more clarification, in spite of the fact that reams of material have been published on this subject. What is a HPA? Are procurement types really professionals such as attorneys, engineers, accountants, doctors, economists, etc.? What are the real functions and responsibilities of a contracting officer?

- effective work force development and utilization and measurement of productivity continues to be a weakness. Right here at West Point the two key procurement people are leaving, one on reassignment and one on retirement. How can we assure that the Superintendent will not now suffer unduly for want of a procurement capability? In the larger national spectrum, how might we better assure a continued strong capability to provide responsive procurement service?

The foregoing entries to the general list represent only one man's observations. Perhaps it would be well to conduct a continual market research effort to maintain clear visability of the viewpoints of our professionals all through the diverse procurement program to know our weaknesses and what our self improvement goals ought to be. In this way, knowledge about our real goals could serve to define our real problems which in turn could help us understand our needs for, and perhaps the appropriate dimensions and modes of, formal research efforts.

Thank you.

To more specifically consider the dimensions of procurement research, let us now hear from Dr. Joseph L. Hood.

SEQUENTIAL RESEARCH NEEDS IN THE EVOLVING DISCIPLINE OF PROCUREMENT*

by

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INTRODUCTION

Much of the effort toward a broader definition of research in procurement seems to present the perspective toward research in a single time dimension. Is it possible that the research needs of a field of study and practice, such as procurement, also vary over time?

Criticism has been leveled at procurement by scholars and practitioners of older disciplines for the naivete of that research. Reactions to these criticisms have been a combination of guilt feelings, defensiveness and scapegoating. It is true that research in procurement is mostly descriptive, with heavy emphasis on surveys, case studies, and reports of individual experience; and it ought to be more analytical and experimental (guilt feeling). But pioneers who are so busy building a new field don't have the time to engage in more scientific research (defensiveness). Besides, it may be the fault of the older disciplines that procurement research is in the state it is--they haven't shown enough interest in our field to bring their discipline to bear on it (scapegoating). The growth of a field of practice like procurement is a genetic-like process which proceeds as if by natural law according to an organically-determined sequence of phases of development. If this is true, a field of practice may have developmental knowledge needs that change through the stages of maturation. So, what are the developmental knowledge needs for procurement research?

Institutional leaders, sponsoring procurement research, and consultants and students, in their constant quest for research problems that would be relevant to the needs of the field of procurement, sometimes

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*The contents of this paper are adapted from Malcomb S. Knowles' speculative theory for "Sequential Research Needs in Evolving Disciplines of Social Practice," Adult Education, XXIII, 4, 1973.

appear to look introspectively at problems and concerns. They seem to search the periodical literature to discover needs as perceived by the leaders of the field. They apparently then explore the research problems being studied in related fields for clues as to what the procurement field ought to be concerned with. These are sometimes good sources for building a master list of possible procurement research problems.

But what many have been asking for is a criterion for helping them select from the list those problems that would be in tempo with the developmental knowledge needs of the field. And this we have not had.

Toward filling this void, a theoretical construct of sequential research needs in the evolving discipline of procurement is presented in the form of six sequential or developmental phases:

1. Definition of the Field.
2. Differentiation of the Field.
3. Standard-Setting.
4. Technological Refinement.
5. Respectability and Justification.
6. Understanding of the Dynamics of the Field.

The following discussion presents each of these phases in terms of (1) the kinds of questions or issues to be addressed, (2) the different types of research activity within the phase, and (3) examples of individual research within each phase that has already been performed.

DEVELOPMENTAL NEEDS FOR RESEARCH IN PROCUREMENT

PHASE 1: DEFINITION OF THE FIELD

The first organic need of a field of social practice such as procurement is for a definition of itself. As the pioneers of a new kind of practice start becoming aware of the fact that they are doing something different and start bumping into others who are doing much the same thing, they begin to get a sense of identification with one another. And then they start asking such questions as: Who else is doing this kind of thing? How many are there? Where are they located? What types of institutions are they in? What, exactly, are they doing and how? What are their objectives? Who are their clients? What terminology are they

using to describe themselves and their work? Under what conditions are they working? What are their resources? What are their problems and concerns? What are their characteristics? In what directions are they moving? These and other questions arise out of the natural need for a new field to become defined. The field of procurement practice needs to be described before it can be presented with integrity.

Accordingly, during this phase the great need is for descriptive research--descriptive surveys, census studies, case reports, demographic studies, and the like. These studies aim to establish the boundaries of the problem, sharply delineate the character and extent of important aspects of the situation or context, and establish a baseline for further analysis and managerial action.

The studies are frequently done by staffs as part of larger projects, e.g., the initial survey of the Air Force pricing capability done by the Air Staff and major commands under the COPPER IMPACT Project (1), and research studies--Hitt's study describing the priorities and functions performed by the Base Procurement and Contracting Officers (2) or Goss and Lockwood's description of the priorities and functional responsibilities of SPO versus AFPRO production functions (3). In other cases, descriptive research involving regulation and library research has been necessary to begin deeper study of a particular area of management concern. In the area of Foreign Military Business, studies by Materna (4), and by Carver and Walsworth (5), attempted to describe fully the procedures, responsibilities, and major actors involved in the DD Form 1513 processing sequence and the NATO supply system.

While none of these studies could be considered conclusive, most did not use hypothesis testing, and none employed the utmost in methodological rigor, they have each provided important knowledge. They have provided a baseline. Additional research can be structured around the gaps and problem areas established by the initial studies. Initial definitions of the terminology and functions characteristic of the field studied are offered for the use of future researchers and the next researcher has a beginning conception of the area of study which enables him to proceed at a more rapid rate than would be possible otherwise.

As additional research is concentrated into an area of concern, the research becomes more specialized. Terms become standardized, and both researchers and practitioners become aware that they are working in a distinct field which they can describe and analyze more rigorously. When this process has matured, the field of study may be said to be differentiated. It now enters Phase 2.

PHASE 2: DIFFERENTIATION OF THE FIELD

As a field of practice becomes identified, it begins to be differentiated from other fields of practice and relationships with them (such as procurement with the fields of accounting and law) become clarified. Questions such as: Exactly how is it different from other related fields of practice in its goals, values, auspices, clientele, and methodology? In what ways does it compete with them versus complement them? What unique needs is it meeting that can't be met equally well by established fields? What right does it have to claim special resources for itself? What specialized training or talents are required to engage in its field of social practice? must be answered.

During this phase there is need for (1) comparative studies that delineate roles and technologies among the fields of practice, (2) exploratory research that probes boundaries, (3) reports of artistic practice that establish uniqueness of approach, and (4) analyses of need.

Frequently, at this stage, the function concerned with performance has become differentiated; and job descriptions, etc. are now more tightly drawn. Parallel staff elements have frequently been formed and the question of training becomes of concern.

Perhaps the clearest example of this type of an area is that of contract pricing. In the Air Force, pricing has become a differentiated, highly skilled subset of the procurement function. Price analysts are recognized as requiring particular talents and analytic skills. Special courses have been set up under the COPPER IMPACT Program to improve and maintain these skills and the respective staff elements and schools maintain a healthy interest in these matters. Knowledge about the pricing activity, however, remains immature. There is need for additional studies to place a firmer foundation under important aspects of the function.

There is currently much emphasis on research involving models. Frequently the models are differentiated with regard to specific areas of concern, such as the model developed by Weida (6) for predicting R&D costs, or that of Karsch (7) for estimating total system cost. New models are introduced to direct attention to variables that have been identified by previous models but not satisfactorily treated. The development of the Entropic Cost Model by Martin (8) and the subsequent case study tests of the model by Glover and Lenz (9), and Babiarz and Giedras (10), exemplifies this process.

As the field becomes better understood, subpractices begin to develop; and specialization in these is observed. As research demonstrates its ability to improve performance, functional staffs become concerned with the problem of maintaining currency and improving the credibility of field

performance. At some point in this process, the field frequently enters Phase 3, Standard-Setting.

PHASE 3: STANDARD-SETTING

Once a field of social practice is clearly defined and differentiated from other fields (in a sense, once its right to membership in the applied social sciences is established), the problem of control arises. Questions such as: What are the standards of practice now observed? What should be the minimum standards of practice? What outcomes are actually being achieved through its practice? What are the appropriate criteria for evaluating the effectiveness of its practice? What procedures should be used for measuring its effectiveness? What sanctions are available and effective in maintaining accepted standards? How should training institutions be accredited and practitioners be certified? must be addressed.

During this phase the greatest need is for (1) normative-descriptive research which yields insight as to desirable standards, (2) evaluative research which appraises the outcome of both training and practice, and (3) instrumental research which provides improved tools and procedures of measurement.

Research is frequently shifted back to staff organizations for performance at this stage. As recognition and acceptance of the area grows, the means of institutionalization are further explored.

Frequently, one of the primary means of institutional identification is begun or at least seriously considered; establishment of a certification program. Thus, we find certified public accountants, certified professional engineers, certified teachers, and certified professional contract managers. All of these involve programs which establish the standards to be exemplified by practitioners. Testing procedures are involved, and depending on the degree of recognition, are sometimes operated by governmental bodies such as those used by accounting, law, medicine, etc. Educational curricula assume greater importance, and the certification bodies and other organizations are entrusted with insuring that education remains both current and pertinent to the needs of the profession.

The DMET System within DOD, the emerging concern with curricula on the part of the Federal Procurement Institute; and, of course, the recent professional certification (Certified Professional Contract Manager) exemplify this feature. As the staffs and professional cadre perceive

their limitations more clearly, they initiate movement into the next phase, Technological Refinement.

PHASE 4: TECHNOLOGICAL REFINEMENT

As a field begins to get feedback from evaluative research, areas of weakness are discovered in its technology. Many of the methods being used are found not to be producing the desired outcomes. And so a need develops for improvement of technology (such as the use of new procurement techniques).

During this phase, the need is for (1) experimental research which tests the relative effectiveness of different approaches, (2) case studies which deepen the understanding of the dynamics of the technology, and (3) action research which continuously infuses the technology with the insights of reality. In this phase, the models of Phase 2 become much more rigorously tested and more appeal is made to empirical analysis. Data bases are refined and become sufficiently well agreed upon to provide the basis for more powerful research methodology. Hypothesis testing research begins to appear and is directed at establishing the efficacy of the models and defining clearly the criteria for their use.

Within the area of pricing, for example, research now is aiming at a more complete understanding of the effects of different means of treating inflation (Gaver and Geisel (11), Brush (12), et. al.). Contract incentives have been much studied (Belden (13), Parker (14), Hunt (15), et. al.), and research has begun to concentrate on the ways to obtain best results from award fees, performance incentives, cost incentives, etc. (Runkle and Schmidt (16), et. al.). As the practitioners and managers involved with the area of knowledge gain confidence, they begin to perceive the need for a different type of research. Knowles identifies these new studies as legitimation efforts aiming at Phase 5, Respectability and Justification.

PHASE 5: RESPECTABILITY AND JUSTIFICATION

As a field gains the stability that comes from definition, differentiation, standard-setting, and technological refinement, a need for status and esteem develops. Needs for survival and safety have been satisfied and now the emphasis is on recognition as a field worthy of respect.

During this phase the need is for: (1) historical research which provides the respectability of accumulated experience, (2) biographical

studies which cast the aura of illustrious figures on the field, and (3) field-evaluative studies which demonstrate the effectiveness of the field in accomplishing its goals. During this phase, also, there is a need for a more sophisticated round of survey-descriptive and comparative studies to show how far the field has matured since its original definition and differentiation.

Many examples can be cited from within the procurement practice to exemplify this phase. The Commission on Government Procurement was an example. Beginning with a rigorous view of the procurement practice as it existed, the commission established a library, performed extensive research, and made numerous recommendations. Many commission staff members have gone on to achieve illustrious reputations in the procurement field. Conferences and symposia become established featuring research into the field and the provision of research-oriented findings to the attendees, as opposed to policy promulgation or "how to" subject matter. The founding of the DOD Procurement Research Symposium in 1972 and its continuation exemplify this feature of Phase 5. With continuing research shedding light on problems and providing tantalizing hints of how better methodologies might be employed to cope with these problems, the field becomes more aware of its internal structure and also of the external forces that shape it. It thus moves into the last and continuing phase of a mature field; the sixth phase, Understanding of Its Own Dynamics.

PHASE 6: UNDERSTANDING OF THE DYNAMICS OF THE FIELD

Once a field has become well established and is esteemed, the need is perceived to understand the internal and external forces that are affecting its development. It now raises such questions about itself as: What are the functional elements of the field and how should they be organized into a unified system? What are the resistances to change in the field? What are the changes in society to which the field should be responding? What are the societal models the field should be trying to work toward? What are the processes by which the direction of movement of the field is determined; and what should they be?

During this phase, the need is for: (1) institutional studies which will shed light on the internal structure and stresses of the field, (2) environmental studies which will identify societal trends to which the field should be responding, (3) force field analyses which will reveal resistances to change, (4) systems analyses which will indicate the interrelationships among the elements of the total system, and (5) prediction studies which will project alternative directions of future movement and test their consequences.

The evidence suggests that the field of procurement practice is, in some aspects, entering Phase 6. The emergence of the concept of

acquisition procurement, embodied in the Commission on Government Procurement's report and in OMB Circular A-109 is an indication. Studies such as those performed by Waldman and Rutledge (17) and Pratt and Marshall (18) on the identification of important variables bearing on the negotiation process and of the identification of the linkages of these variables to organizational elements become appropriate to identify important interrelationships. The existence of these and promotion of further studies into organizational interrelationships may be regarded as exemplifying the field's arrival and maturation.

Thus, based on Knowles' conception, the field of procurement has, in some respects, reached maturity. This happy state is not, however, reached across the board, nor is it a continuing state that once reached can be expected to persist indefinitely. Indeed the opposite is true. Because the field is recognized as a profession, greater responsibilities are placed on it.

As its understanding of its relationships with other functions grows, the profession is faced with the need to increase its knowledge and to maintain pace with the important outside forces frequently generated by collateral functional areas. As knowledge advances, subareas within the profession are identified, and begin the quest for complete understanding of themselves. Thus, at a given time, research within the practice can and should be found exemplifying each of the preceding phases. In fact, the character, quality, and extent of research under way may be regarded as an important indicator of the practice's vitality.

This conception of the developmental needs for research in a field of practice such as procurement can be summarized schematically as follows:

Phase	Organic Need	Relevant Research
1	Definition of the Field	Survey-descriptive studies Census studies Case reports Demographic studies
2	Differentiation of the Field	Comparative studies Exploratory studies Reports of artistic experience Need analysis
3	Standard-Setting	Normative-descriptive studies Evaluative research Instrumental studies

Phase	Organic Need	Relevant Research
4	Technological Refinement	Experimental research Case studies Theory-building Action-research
5	Respectability and Justification	Historical studies Biographical research Field-evaluative studies Survey-descriptive studies Comparative studies
6	Understanding of the Dynamics of the Field	Institutional studies Environmental studies Force-field analysis Systems analysis Prediction studies

QUALIFICATIONS

There are two qualifications to the presentation of this construct so far. First, the phases should not be viewed to be as distinct and separate as this classification makes them appear. It may be necessary to have overlapping among two or three adjacent phases. For example, while a field is working on its definition, there may be some work going on legitimately on differentiation and perhaps even on standard setting.

In the second place, the phases should not be considered as being linear; rather, they should be viewed as being spiral. An evolving field may need to move through the six phases a first time fairly superficially and then to repeat them in ever deeper cycles. The time span for each cycle may become shorter and shorter.

USES OF THIS CONSTRUCT

This theoretical construct is presented in the hope that it will be used in at least two ways.

First, it should be put to a rigorous intellectual test. How do these speculations stand up in the light of the experience, intuition,

and logic possessed by the procurement community? Does the notion of genetically-determined phases of development of a field of practice make sense? If not, what alternate guidelines to the suggested patterning of research make more sense? If the idea of the developmental phases makes sense, how do the six phases hold up to analysis? Is the sequence correct? Should other phases be added? Have the relevant types of research for each phase been identified?

Second, the construct should be tested empirically. Institutional leaders, as well as researchers, should try to apply it to the selection of procurement research problems. Moreover, they should report whether or not it holds up as a criterion of relevance for procurement research in its different developmental and environmental stages.

IMPLICATIONS

As a way of organizing our knowledge, the Knowles' construct has important implications for procurement institutional leaders. Public demand for improved efficiency, effectiveness, and accuracy in procurement is frequently expressed as a need for improved procurement policy and procedures. Research studies providing better understanding and analysis of the procurement process can contribute to meeting the public's expectations. Management can act or refuse to act, using research findings as an important part of the decision process. In fact, some of the examples cited for each of the developmental phases have influenced changes in procurement policy, practice, and organization.

However, what can be accomplished through research is different depending on the knowledge base. Sophisticated models cannot be developed until a rigorous and agreed on description of the pertinent aspects of the system is available; accepted standards will not be forthcoming until normative research has become an integral part of the knowledge base, etc. Thus, the research of the past provides the framework by which we understand the present situation and identify the future's needs. By focusing our research activities on the most pressing knowledge needs and avoiding premature commitments, management can set the stage for orderly improvement.

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PROCUREMENT RESEARCH IN GAO:

DETERMINING WHAT TO PROCURE

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SLIDE 1

GAO's role in "procurement research" is an indirect one by virtue of its unique position in Government. That demands some explanation and even in this audience some background on GAO is in order.

SLIDE 2

The purpose of the Budget and Accounting Act of 1921 was to provide a national budget system and an independent audit of Government accounts. To accomplish these goals the act established a new Bureau of the Budget to compile the President's budget, and created the United States General Accounting Office, independent of the executive departments. GAO is headed by the Comptroller General of the United States who is appointed by the President, with the advice and consent of the Senate, to serve 15 years. He may be removed during his term only by impeachment for incapacitation, inefficiency, neglect of duty, malfeasance in office, commission of a felony, or conduct involving moral turpitude. Therein lies the basis for the non-political objectivity of the GAO.

SLIDE 3

Authority is broad.

SLIDE 4

From its inception the GAO has been responsible for determining the legality and accuracy of receipt, disbursement, and application of public funds SLIDE 5 with the objectives of greater economy and efficiency in public expenditures.

SLIDE 6

Subsequent practice and legislation, confirmed in the Legislative Reorganization Act of 1970, made the GAO responsible for reviewing the performance obtained from public expenditures - the objective in this case is increasing the effectiveness of public expenditures.

SLIDE 7

The responsibilities are carried out in many ways. The more significant are:

1. Financial and Compliance Audits.

2. Management Reviews of Economy and Efficiency.

3. Program Results Reviews.

SLIDE 8

Any of you who have been subject to GAO audit know what these categories entail.

SLIDE OFF

Other vehicles include:

Published and Unpublished Decisions of the Comptroller General on new or novel questions of law, or out of the ordinary circumstances.

Government Contract Bid Protest Decisions.

Participation in the Joint Financial Management Improvement.

Program.

Participation in the Cost Accounting Standards Board.

We help the Congress in its legislative oversight function by providing its committees and members with timely information, analyses, and recommendations concerning the operations of Government.

Mr. Staats feels our greatest contribution is to provide answers to such questions as:

--Is it possible to eliminate waste and inefficient use of public monies?

--Are Federal programs, whether administered directly by the Federal Government, or through other organizations such as State and local governments, achieving their objectives?

--Are there other ways of accomplishing the objectives of these programs at lower costs?

--Are funds being spent legally and is the accounting for them adequate?

He has summed up our mission as "recommending ways to make Government work better"--doing this as much as possible by making the results of our studies known before options are lost.

SLIDE 9

The farther along a major acquisition, for example, proceeds the greater the reluctance to reconsider, revise, defer, or terminate a program.

SLIDE 10

For many years the GAO had been organized along lines which provided agency coverage. Many of you may be familiar with the Defense Division which examined DOD's Research and Development, Facilities, Supply Management, Procurement, and, beginning in 1969, Major Acquisitions.

SLIDE 11

The Procurement and Systems Acquisition Division was established as part of a major realignment in the organizational structure of GAO, effective April 3, 1972. The reorganization was an outgrowth of an internal study which concluded that the accounting and auditing divisions of GAO should be organized on a function and program basis, in part to accelerate the growth of functional and program expertise among senior staff.

SLIDE 12

Back in 1967, Mr. Staats began a program to get greater diversity in the staff and this continues.

SLIDE OFF

PSAD was conceived as one the functional divisions, with responsibilities spanning the entire spectrum of the procurement function, and the science and technology policies and programs of the Federal Government. PSAD is the focal point within the Office for general understanding, coordination, assessment, guidance, and communication on what has been done, what is being done, and what should be done relative to these two issue areas (of 29 currently) and serves as advisor to all other elements of GAO.

The Division is concerned with (1) the identification of needs and establishment of requirements, (2) the identification of technology gaps, (3) the support of research and development, and (4) the ultimate acquisition by the Federal Government of goods, services, and facilities of requisite quality, within the time needed, at the most advantageous cost, through the use of contracts, leases, and grants.

We do this through:

(1) Government-wide and multiagency functional audits of --

(a) Overall policies, practices, and programs of the Federal Government relating to procurement including the acquisition of new items.

(b) Overall policies, practices and programs of the Federal Government relating to research and development including the Federal Government's role for aiding and influencing science and technology to help meet the many complex challenges facing the nation.

(2) Management and program audits of the --

(a) National Aeronautics and Space Administration.

(b) Weapons procurement activities of the Energy Research and Development Agency.

(c) Procurement functions (exclusive of the Public Buildings Service construction) of the General Services Administration.

(d) Renegotiation Board.

(e) Functions, programs, and activities of the Department of Defense, not specifically assigned to other GAO divisions.

(f) Other activities, boards, commissions, and committees of the Federal Government:

Armed Services Procurement Regulation (ASPR) Revisions.

Central DOD overhead agencies (e.g. OSD, DLA, NSA).

Committee on Purchases of Blind-Made Products.

Implementation of Recommendations of the Commission on Government Procurement.

Emergency Loan Guarantee Board.

These agencies are responsible for most of the Federal Government's annual expenditure for procurement and science and technology. In addition to the direct activities of the Federal agencies, grantees, using Federal funds, procure a large but unknown amount of goods and services and contribute significantly to the advancement of science and technology.

Another of our responsibilities is monitoring compliance with OMB Circular A-76.

SLIDE 13

In FY 76 we spent about 10% of our resources on procurement as an issue area but that figure is misleading. The other divisions do work that includes procurement issue coverage but they identify the work by their own issue area.

SLIDE OFF

There's a lot of lee-way in what's appropriate to do at any point in time. We need to be sensitive to changing times and put out resources to work where we see the chance for making the biggest contribution. Today, certain recurring themes appear on the national scene which should trigger our planning. For example:

--The low level of public confidence in the integrity of Government, and particularly in contracting activities, would seem to dictate our addressing this issue--clearing the air where appropriate, exposing looseness in controls and abuses where found, and supporting reasonable safeguards, where needed.

--Spiraling defense costs during peacetime would suggest opportunities for our participation with Congress in a closer scrutiny of the Administration's Defense strategy and spending rationale--particularly involving costly and sometimes questionable or oversold weapons systems.

Regardless of what happens to be the issue of the moment, how much we're working within the mainstream of public thought, or how well we're anticipating congressional needs, we still might not be effective. To borrow a thought from Mr. Staats:

"We would rather issue concise and informative letters, getting them into appropriate hands at the right time, than be able to point to stacks of bound reports--all too late to be useful. Ideally, our best product is a timely report to the Congress containing recommendations for improvements to procurement policies and/or practices."

In highly general terms, PSAD is trying to contribute to improvements in Procurement policies and practices. We do this basically in two ways:

--By providing information and independent evaluations to Congress, its committees and members on high visibility procurement, and science and technology--including major acquisition--programs and issues, and

--By continually chipping away at significant management weaknesses.

I'm not sure I could, or would want to attempt to list our contributions to procurement. Perhaps you are the only ones who can do that. I find it interesting that only about 40 GAO reports are included in the procurement research guide.

SLIDE 14

One thing I think there is agreement on and that is that we contribute to more effective, efficient and economical Government because GAO exists and its presence is recognized.

I've left a variety of GAO documents in the lobby for those who are interested, and provided Bob Williams with a listing of some 300 reports we have issued from July 1974 to April 1977.

SLIDE 15

In 1969 the rising cost of major weapon systems, which continues to rise, inflation not withstanding, led to the creation of the major acquisitions subdivision.

SLIDE 16

The initial efforts reported only on the cost, schedule, and performance of selected individual systems. We soon broadened our reviews to include functions which cut across all systems - cost estimating, program management, cost/benefit studies, test & evaluation, and program management.

And in 1973 we began reviewing major civil acquisitions.

SLIDE 17

The Budget and impoundment Control

Act of 1974 created the Budget Committees of the Congress and the Congressional Budget Office and made a third key committee of each house to oversee the DOD budget. This congressional budget structure has the effect of further implementing the recommendations of the Procurement Commission because in January 1978 the President will present a mission oriented budget.

This has increased the trend in the authorization and appropriation committees to move toward mission area consideration of the Defense budget.

More recently we have begun reviewing groups of related systems in a mission area context.

SLIDE 18

Here are the dos and don'ts.

The Comptroller General and the Commission have both stated that the biggest problem is determining what to procure and for what purpose.

The Commission noted that problems encountered during procurement are rooted in action or inaction of earlier phases--the identification of needs, establishment of requirements, or "front-end" of the acquisition process. The latest GAO report mentioned in the procurement research guide is our 1974 report on Identification of Needs and Establishment of Requirements for Major Weapon Systems.

SLIDE 19

I like to consider the familiar DOD pipeline chart as representing the major acquisition process. It covers two broad activities:

--Determining what to Procure.

--Determing how to Procure it.

SLIDE 20

OMB Circular A-109 implements the Commission's recommendations on "front-end" planning and in DOD the formal recognition of Milestone 0 gives visibility to an as yet unnamed phase of the acquisition process.

SLIDE 21

How about Identification and Definition Phase?

SLIDE 22

This new phase includes:

Analyzing the agency's mission in relation to national needs.

Reconciliation of agency component roles and missions.

Intelligence -- collection, processing, and reporting.

Threat assessment at various levels by those who must face the threat and counter it, and by an analysis organization reporting to the agency head.

Technology assessment and the push of technology relative to the pull of the threat.

Assessment of existing resources and capabilities.

A need may be uncovered as a deficiency resulting from a change in mission, threat, or environment, the application of new technology, or the recognition of an omission or void in existing capabilities.

As there is almost always some limitation on resources, and competition among programs for available resources usually exists, it is necessary to assign some priority on which needs will be dealt with first, or to establish the general magnitude of resources which may be invested.

Generally, all of these things have been done in the past in preparing the Program Objectives Memorandum to support the FYDP.

Now the approved mission needs which comprise the POM will be specifically identified and approved, and the affordability determinations made by the Secretary of Defense and Services Secretaries will no longer be hidden within the overall PPBS.

SLIDE 24

Something new is added to the Conceptual phase as well. Approval of the mission need grants authority to explore alternative methods of satisfying the need with emphasis on generating innovation and conceptual competition from industry! Tomorrow we may get some insight from industry and OFPP as to how this will impact the process.

Trade-off studies of cost, schedule and performance become more complex and important.

Risk analysis of new concepts or unproven technology combines subjective judgment with quantitative methods.

Economic analysis of the alternative concepts--over the life of the concept and in relation to other political and economic goals--becomes critical.

I was happy to see the terms acquisition and procurement used interchangeably in the program and discussions.

If you are a procurement purist you may decide that procurement research only concerns itself with the letting of contracts for obtaining alternative solutions.

GAO however is responsible for the application of all public funds and we must examine the very complex and significant operation of determining what to procure.

SLIDE 25

Finally - the Budgeting and Accounting Procedures Act of 1950 established the Joint Financial Management Improvement Program - the C. G. is the leader. P. L. 91-379, Aug 1970 established the Cost Accounting Standards Board. The C. G. is Chairman of the Board.

Congress has not seen fit to specify a Joint Procurement Improvement Program as such. OFPP, the FPI, and these symposia I suppose constitute the current effort.

Would it benefit from being identified as a program?

SLIDE 26

If so, where is the overall Management Improvement Program it supports?

UNITED STATES GENERAL ACCOUNTING OFFICE

SLIDE 1

- AN INDEPENDENT AGENCY IN THE LEGISLATIVE BRANCH OF THE GOVERNMENT
- CREATED IN 1921 BY THE BUDGET AND ACCOUNTING ACT
- HEADED BY THE COMPTROLLER GENERAL AND THE DEPUTY COMPTROLLER GENERAL, EACH WITH 15 YEAR TERMS
  - ELMER B. STAATS - APPOINTED IN 1966 AS FIFTH COMPTROLLER GENERAL
  - ROBERT F. KELLER - APPOINTED IN 1969 AS DEPUTY COMPTROLLER GENERAL
- SIZE - ABOUT 5,500 EMPLOYEES
- LOCATION - HEADQUARTERS IN WASHINGTON, D.C.

  REGIONAL OFFICES IN 15 MAJOR CITIES

  OVERSEAS OFFICES IN FRANKFURT, HONOLULU, BANGKOK AND PANAMA

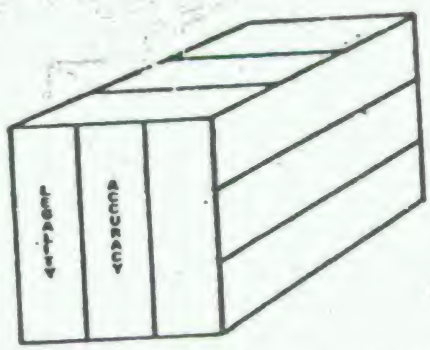
SLIDE 2

AUDITING

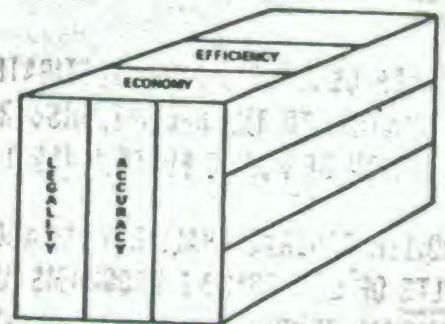
AUTHORITY IS BROAD

- "THE COMPTROLLER GENERAL SHALL INVESTIGATE....ALL MATTERS RELATING TO THE RECEIPT, DISBURSEMENT, AND APPLICATION OF PUBLIC FUNDS." (1921 ACT)
- "THE COMPTROLLER GENERAL SHALL REVIEW AND EVALUATE THE RESULTS OF GOVERNMENT PROGRAMS AND ACTIVITIES..." (CONGRESSIONAL BUDGET AND IMPOUNDMENT CONTROL ACT OF 1974)

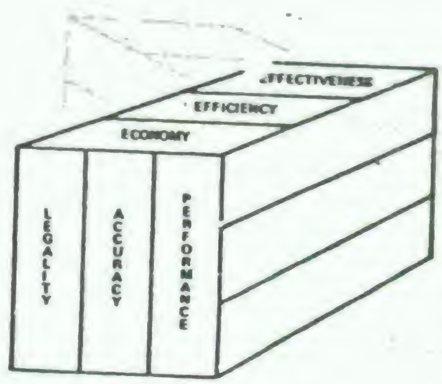
SLIDE 3



SLIDE 4



SLIDE 5



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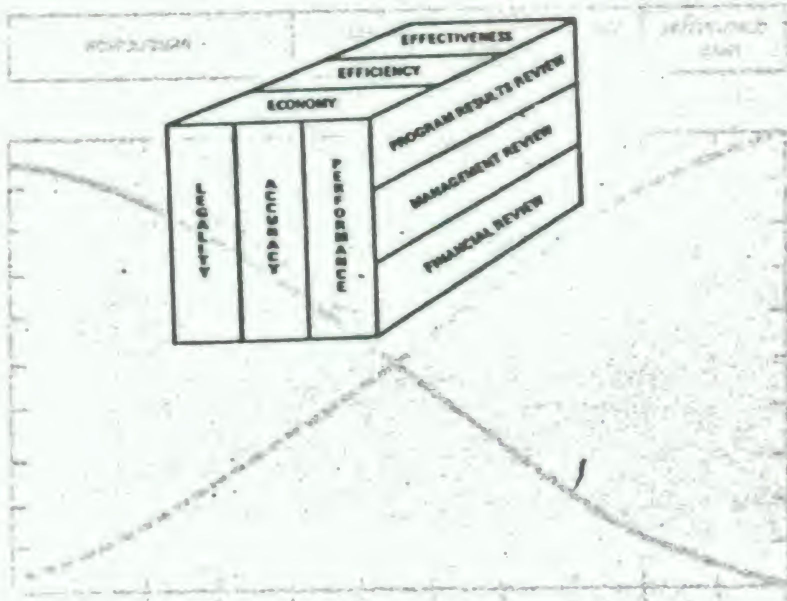
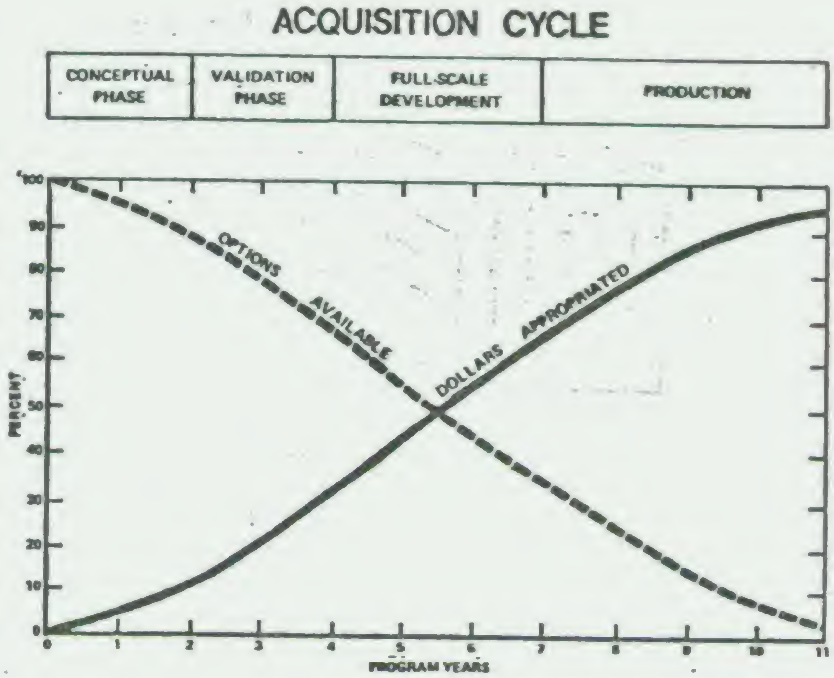


SLIDE 7

CATEGORIES OF AUDIT

- FINANCIAL ACCOUNTABILITY
  - PROPRIETY, ACCURACY, AND LEGALITY OF FINANCIAL TRANSACTIONS
  - SETTLEMENT OF PUBLIC ACCOUNTS
  - RELIABILITY OF FINANCIAL STATEMENTS AND REPORTS
  - ADEQUACY OF ACCOUNTING SYSTEMS
- MANAGERIAL ACCOUNTABILITY
  - EFFICIENCY AND ECONOMY OF OPERATIONS
- PROGRAM ACCOUNTABILITY
  - EVALUATION OF PROGRAM BENEFITS, RESULTS, OR ACCOMPLISHMENTS
  - AND ACHIEVEMENT OF INTENDED OBJECTIVES

SLIDE 8



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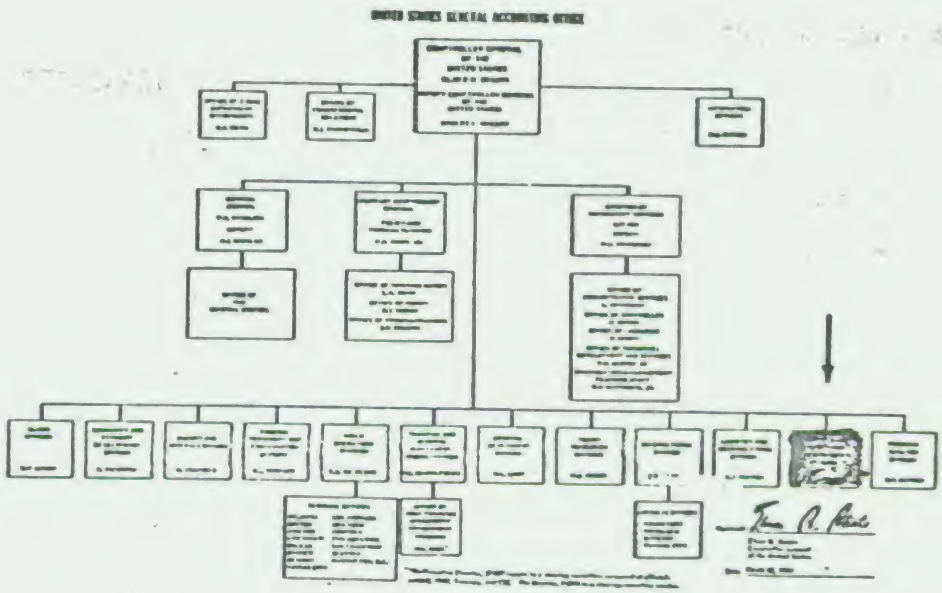
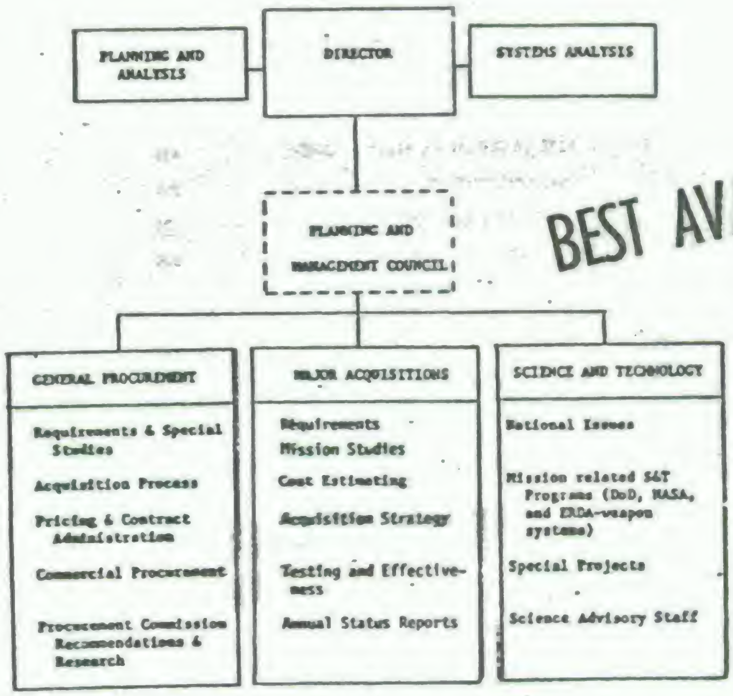


SLIDE 10

PROCUREMENT AND SYSTEMS ACQUISITION DIVISION



SLIDE 11

COMPOSITION GAO PROFESSIONAL STAFF

JULY 3, 1976

ACCOUNTANTS AND AUDITORS	2,643
BUSINESS ADMINISTRATION/MANAGEMENT	909
ECONOMISTS AND OTHER SOCIAL SCIENTISTS	51
ATTORNEYS	129
ACTUARIES AND OTHER MATH SCIENTISTS	89
CLAIMS ADJUDICATORS	36
COMPUTER AND INFORMATION SPECIALISTS	36
PERSONNEL MANAGEMENT SPECIALISTS	26
ENGINEERS	29
TRANSPORTATION SPECIALISTS	5
ALL OTHER	110
	4,063

SLIDE 12

FY 76 (JULY 1, 1975 - JUNE 30, 1976)

PROFESSIONAL STAFF YEARS

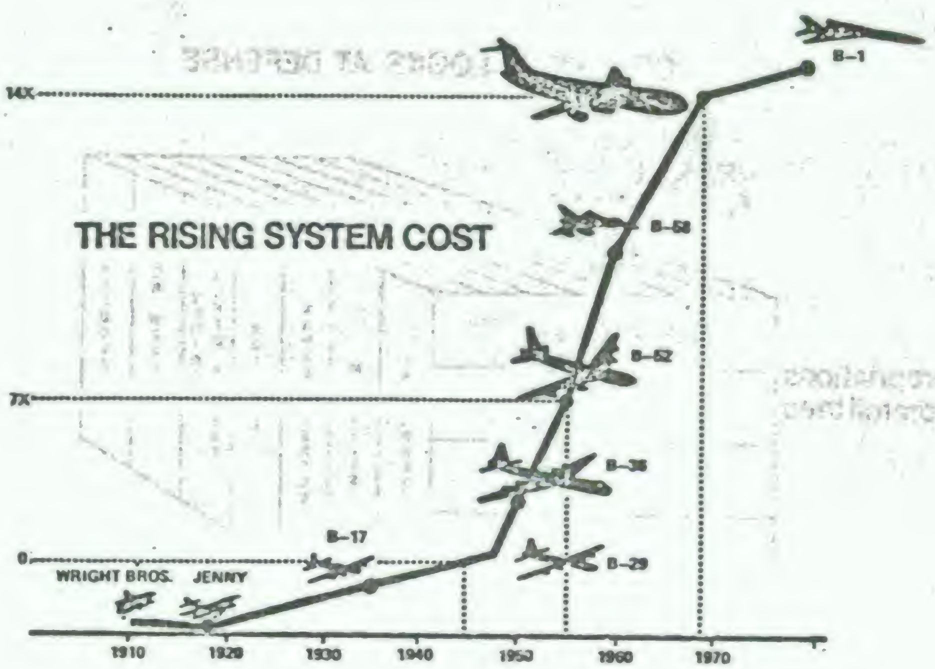
PSAD (PROCUREMENT, SCIENCE, OTHER)	405
PSAD (PROCUREMENT)	281
OTHER GAO (PROCUREMENT)	24
TOTAL GAO (PROCUREMENT)	305
TOTAL GAO	3,039

SLIDE 13

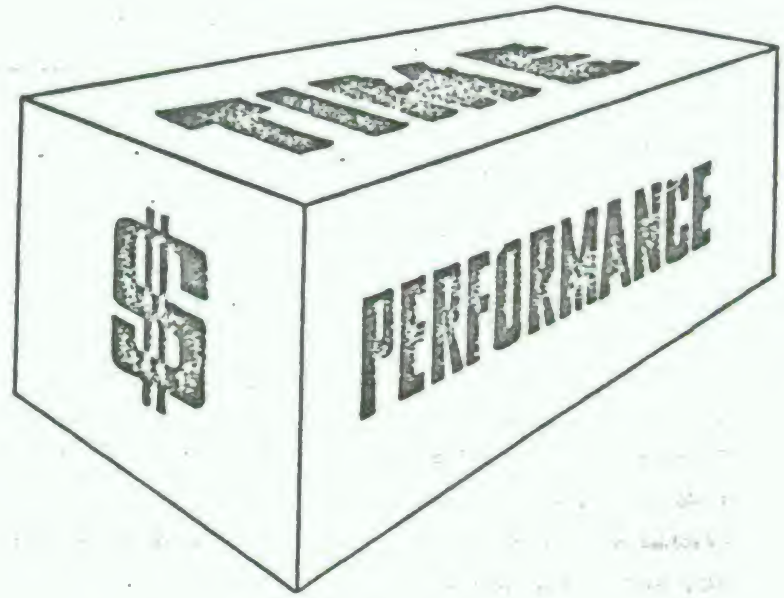
SOURCES OF INFORM[illegible] ABOUT GAO REPORTS

- MONTHLY LIST OF GAO [illegible]PORTS
- LIST OF GAO PUBLICATIONS (SEMI-ANNUAL)
- CONGRESSIONAL RECORD
  - DAILY LIST OF COMPTROLLER GENERAL REPORTS
  - MONTHLY LIST OF GAO REPORTS
  - REFERENCES TO SPECIFIC REPORTS BY MEMBERS
- ANNUAL REPORT OF COMPTROLLER GENERAL

SLIDE 14

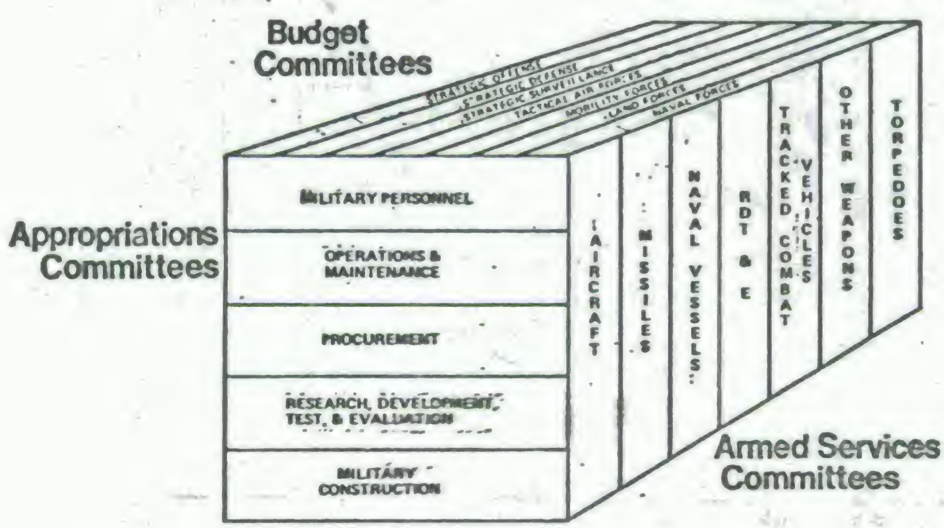


SLIDE 15



SLIDE 16

CONGRESS LOOKS AT DEFENSE



SLIDE 17

MISSION STUDIES

GAO does not:

Define missions.

Make intelligence estimates.

Suggest military policy, strategy, or tactics.

Specify operations requirements for weapon systems.

Suggest appropriate spending levels.

GAO does:

State mission requirements as defined by OSD.

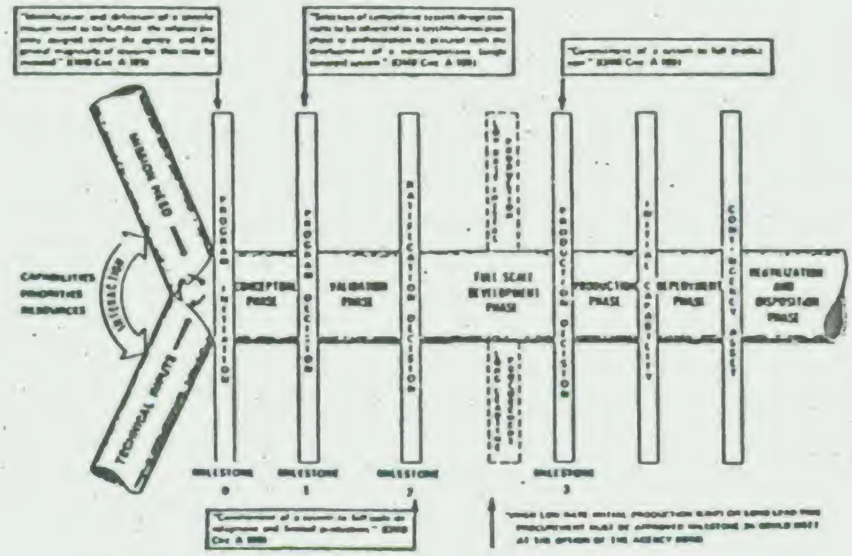
Describe the enemy threat using DOD intelligence data and available threat assessment.

Describe current inventory of weapon systems using available DOD performance data and costs.

Describe current and planned R&D programs, purposes, and projected costs.

SLIDE 18

THE LIFE CYCLE OF A MAJOR SYSTEM



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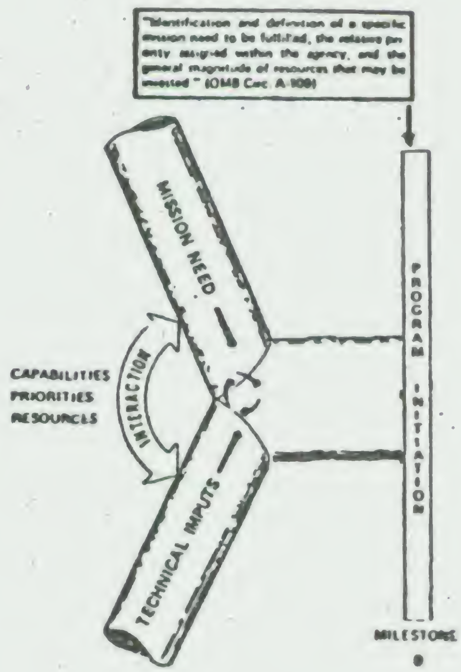

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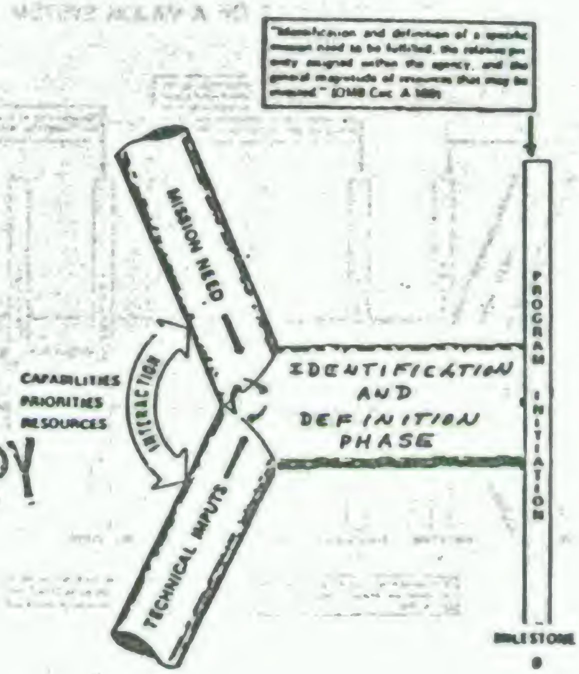

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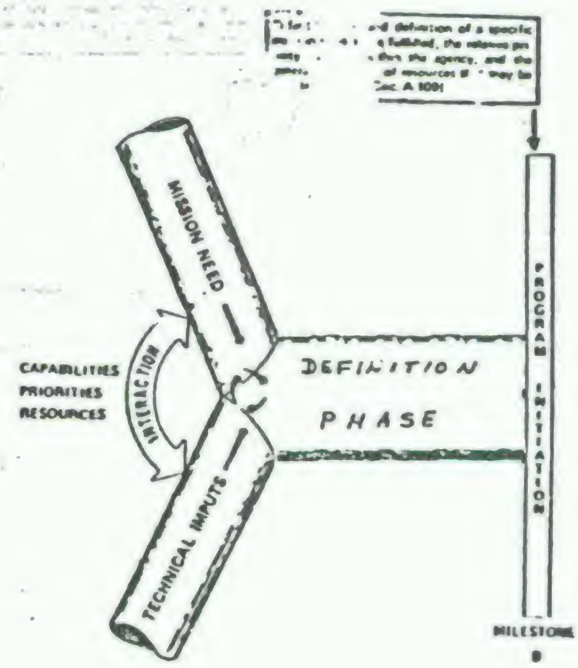

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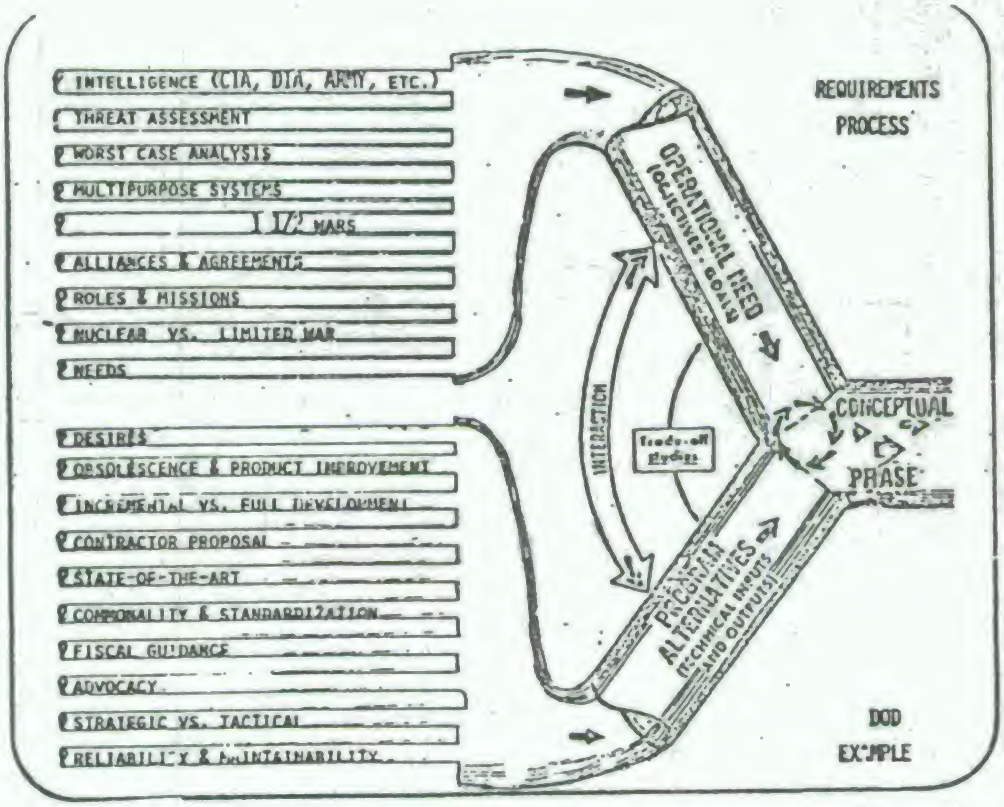

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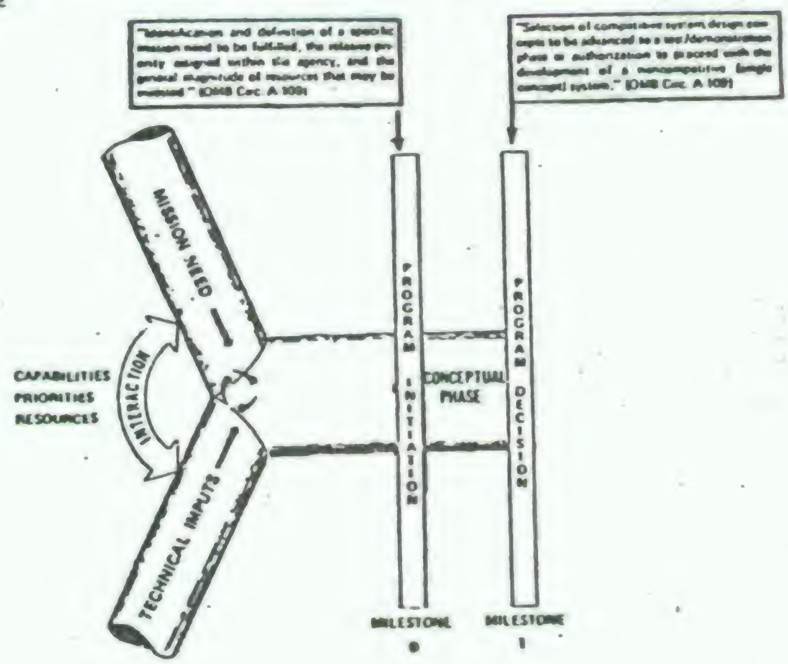

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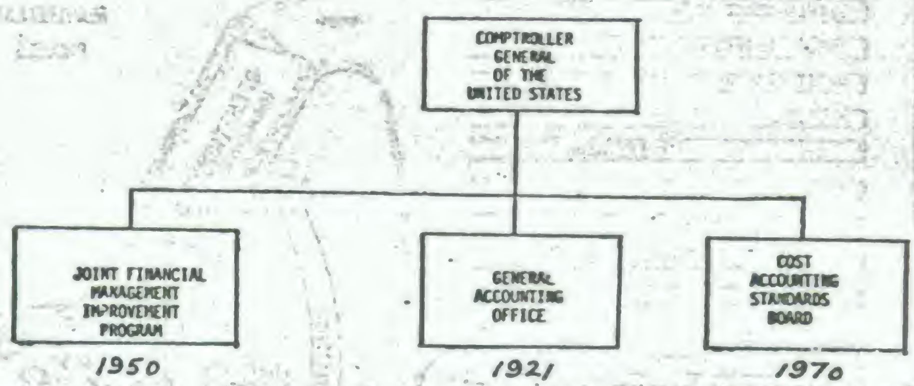

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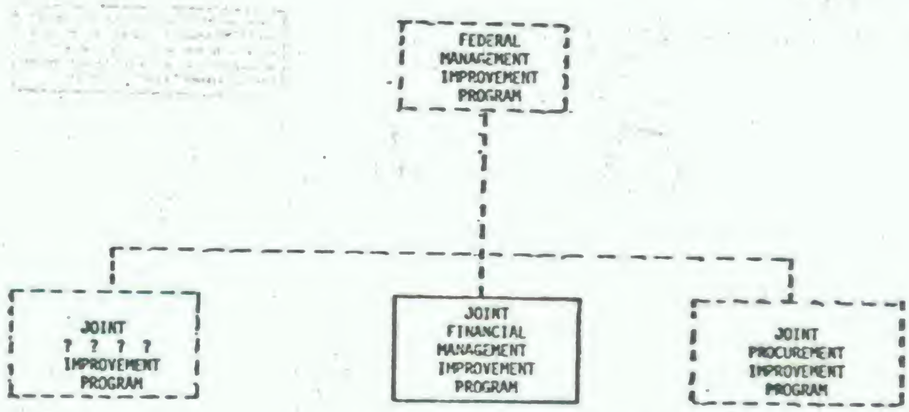

SLIDE 26

PROCUREMENT RESEARCH:
IS THERE ONE BEST WAY?

Major Lyle W. Lockwood
Deputy Director
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Lt Col Daniel E. Strayer
Executive Director
Air Force Business Research Management Center

INTRODUCTION

The release of the findings of the Commission on Government Procurement, the establishment of the DOD Procurement Research Symposium, and formation of the Federal Procurement Institute within the Office of Federal Procurement Policy have drawn attention to the subject of procurement research. These events, by implication, have stimulated a search for better definition of both procurement and procurement research.

Thus, there are attempts to define the boundaries of the process which we call procurement and to define the process by which research of the procurement process is conducted. One paper, "A Proposed Definition and Taxonomy for Procurement Research in the Department of Defense," attempts to define the procurement research process. Another approach to defining the procurement research process is being undertaken by an element of the General Accounting Office (GAO). In both of these endeavors the implication could be drawn that the result will reflect the one best concept, the one best definition, and thus the one best way for procurement research.

The purpose of this paper is to present some observations about the modes and dimensions of procurement research which suggest that the adage "it all depends" may be applicable to procurement research. In short, there may not be "one best way" for procurement research.

Procurement is largely an heuristic process. A variety of rules devised from a variety of sources, using a variety of techniques to satisfy a variety of objectives, are used to influence the structuring and performance of the procurement process. Traditional public elements, i.e., Legislative, Executive, and Judicial Branches of Government, using a spectrum of procurement research techniques promulgate changes in law, policy, and precedent which substantially alter the procurement processes operation.

The Legislative Branch formulates laws affecting the procurement process. Such laws may result from independent investigations, studies by the GAO, public hearings on proposed legislation, and other processes of the public policy formulation process. The Executive Branch influences the procurement process through the promulgation of procurement and acquisition directives, instructions, regulations, and manuals. Studies and research projects often support this process. Other changes, within the limits of authority and law, are implemented as a result of procurement research performed by academicians, contractors, and specifically chartered ad hoc study teams. The Judicial Branch influences the procurement process through decisions made after study and research of the factors pertinent to the case under question. All of these are influenced by procurement research done by private elements involved in the procurement process.

Contractors may employ procurement research to generate improved procurement methods for their own activities or to the procurement policy generation process. Academic institutions conduct procurement research for either the public or private sectors or to satisfy their own quest for knowledge. Industrial and professional associations also conduct studies of the procurement process in response to requests by either the private or public sectors.

Although the reader is challenged to think about the reliance that each of these elements places upon procurement research to satisfy their respective objectives, we will concentrate upon the modes and dimensions of procurement research as conducted within the Department of Defense (DOD). By classifying procurement research into modes and dimensions we can illuminate the complexity of the problem.

PROCUREMENT RESEARCH MODES

Mode can be defined as a manner of doing something or of performing a particular function or activity. Using this definition, identifiable modes of procurement research are: (1) the participants; (2) the form of the output products; and (3) the methodology of the study.

Participants

Participants in procurement research are initiators, researchers, data sources, and recipients or consumers. DOD

procurement research can be initiated as a response to external sources such as Congress, the GAO, or higher levels within the Executive Branch. Agency decision makers can also be initiators of procurement research. These may be procurement officers; Directors of Procurement; and procurement staff elements. On occasion, researchers independently initiate procurement research. Each of the participants may define problems within the procurement process which, with or without acceptance and approval by the other participants, become the basis for initiating procurement research.

Researchers such as ad hoc teams, academicians, and even staff elements also participate in the procurement research process. Researchers may act individually or as organized continuing teams in the procurement management review sense. Researchers may also be organized as ad hoc teams from responsible staff elements. Such specially chartered ad hoc interdisciplinary teams are frequent participants in procurement research.

Students, academicians, and professional researchers also participate in procurement research. Their activities may be gratuitous; that is, they are interested in the procurement process and are conducting research and study into the procurement process to satisfy their personal quest for knowledge. Professional researchers may also be involved.

Data sources also participate in the procurement research process. Many procurement research findings result from interviews and questionnaires supplied by procurement practitioners. Other data sources may be operators of data gathering systems which collect information on the procurement process. Contractor personnel are also participants as data sources which are important in the conduct of procurement research.

Recipients (or consumers) of procurement research may or may not be the same set of people who initiated the procurement research. Decision makers; staff elements; and more often than not, the library, the files, and the desk drawers are the usual recipients and the repositories for procurement research.

Thus initiators, researchers, data sources, and recipients or consumers may be, and frequently are, the same people or elements. They are just wearing different hats at different times. Yet, each carries a different perception of the

research need, approach, data requirements, and utilization of results depending on the circumstances of the research effort. It would be surprising, therefore, if any consensus could be reached about a "one best way" based on the participant mode.

Indeed, given the wide disparity of backgrounds, organizational loyalties, and objectives, it would perhaps be wisest to expect diversity when the participant's view of procurement research is solicited. Agreement on a "best" approach would seem unlikely.

Form of Output Product

The form of the output is also a mode of procurement research. What is desired has great impact on what should be done and on how it should be accomplished. Output products may be one or more of the following: a formal report, a decision, a regulation, or a computer program.

Formal reports are usually documented in a rigid academic style in keeping with the scientific method. The objective is full disclosure of facts and methodology establishing a basis for replication. Other formal reports may be position papers for use by the staff elements or decision makers or a briefing with or without formalized supporting documentation. Another form of procurement research output may simply be a decision to choose one course of action over another. The decision may be reflected in a regulation, directive, or instruction formulated from the findings developed through procurement research activities. This constitutes institutionalization of the research results. In other cases, a computer program is a product resulting from procurement research. Its continued utilization constitutes implementation. Outputs of the research process, like its participants, thus takes several forms and satisfies widely divergent needs. Both the methodology and the ground rules impact on the way procurement research should be managed and how its management should operate.

Methodology

Another mode of procurement research is the methodology employed. Two general categories of methodology are quantitative and qualitative. Quantitative methodologies usually

deal with issues where measurable data are present and the tools of operations research and management science can be applied, often resulting in the use of a hypothesis test. Qualitative-type methodologies draw more upon the behavioral sciences, are descriptive in nature, and often use the research question approach. Of course, combined methodologies may be used in situations dealing with some subjects which require some rigorous subjectivity in their analysis.

CAVEATS

Modes or manners of performing a particular function, in this case procurement research, all operate within certain specified ground rules, constraints, or operating envelopes. These ground rules both limit the outcomes flexibility and provide focus and direction for study. Some of these ground rules for procurement research are: compliance review, evaluation, or improvement and innovation. The compliance mode of procurement research would be used to determine compliance with an existing regulation, directive, or specified practice. A simple hypothesis test might be used. The evaluation mode might be applied to evaluate the efficacy of the procurement process to determine if a change is warranted. This might involve the use of both quantitative and qualitative techniques.

The remaining mode may also be used to seek improvement or innovation within the procurement process itself. In contrast with the compliance and evaluation modes which suggest operation within the limits of regulations, the last case, improvement or innovation, suggests that regulations and formal authority patterns should not be viewed as constraints by the researcher. As we get further from defining the manner in which procurement research is conducted and begin to define factors which influence our view of procurement research, the dimensions of procurement research come into play.

PROCUREMENT RESEARCH DIMENSIONS

Dimension is defined as the set of circumstances or environmental factors within which something is viewed. Some of

the dimensions which are used to view procurement research are the flow, the outcome level, the breadth of application, and the objectivity of the data.

Sequential Flow

One dimension of procurement research which attracts considerable attention is the sequential flow dimension. This starts with the definition of need, followed by the initiation of the project, the conduct of the research, the documentation and presentation of research results, the acceptance and implementation of those results, and the follow-up of the procurement research. This flow is similar to the flow of the acquisition process and is often accompanied with an identification of the decision makers who have the authority to commit resources for research.

The need definition step usually includes defining the problem and planning the study. This is followed by a formal research initiation approval validating the research need and priority. After the research project has been initiated, the research is conducted including actions which select the researcher, the methodology, and identify and obtain the necessary data. These steps are followed by documentation of the study and presentation of the results. Following the documentation and presentation step is the decision to accept the results and/or implement the recommended actions. The implementation step should be followed by a formal process where the results of the implementation are evaluated and possibly a new research project defined and the flow reinitiated.

The sequential view considers each use of research to be equally likely, equally useful. However, social science has evolved additional views of the research process which should be drawn upon in formulating the rules for proceeding. Helmstadter in "Research Concepts in Human Behavior" offers a construct consisting of three dimensions: outcome level, breadth of application, and data objectivity, (Figure 1). This construct, which affects each research effort, provides three more dimensions of procurement research.

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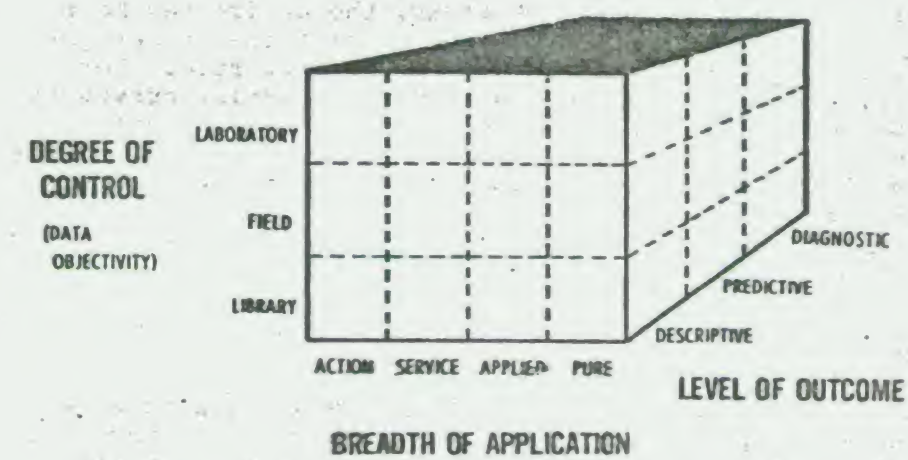
Figure 1
RESEARCH STUDY TAXONOMY



Outcome Level

This dimension addresses the motive for the procurement research project in terms of the outcome desired. If the outcome level is intended to be descriptive in nature, the purpose of the project would be to define what the world looks like. These may be statistically based presentations or qualitative descriptions of the environment in which procurement operates and usually includes a rigorous definition of the process.

Another aspect of the outcome level dimension would be a study which permits prediction of important characteristics. Here the research is directed toward searching for relationships among variables which have some high degree of certainty in terms of their ability to predict the future. Examples of these might be the construction of parametric cost models.

Another desired outcome might be diagnostic research results seeking to offer both prediction and understanding

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of why certain relationships exist; that is, why does a learning curve operate, or why does a parametric cost model work.

Within each of these dimensions, the desire may be to understand the process or subject, clarify the process or initiate a change to the process or decision rule. For example, one could undertake a study of learning curves to seek better understanding as to why they predict cost at the levels that they are predicting. One could also undertake a study to seek clarification of the application of the learning curve to a particular situation, or one could undertake a study which would support changing the learning curve model being used.

Breadth of Application

Another dimension of procurement research, also drawn from Helmstadter, is the breadth of application. Once the results of procurement research are received, the question is in which arena will they be applied. Helmstadter identifies four basic categories; action research, service research, applied research, and pure or basic research. Action research can be argued to not be called research at all. The initiator has no intention of yielding a research product; but intends, like the Hawthorne effect, to gain added efficiency and effectiveness by drawing attention to a particular subject through the conduct of a study or research project.

Service research is usually done at the request of a particular organization or decision maker, and the results are often applicable only to that particular decision maker or setting.

Applied research, on the other hand, is intended to yield findings and results which can be used within a given field or body of knowledge; and pure or basic research is undertaken with the motive of seeking better understanding and knowledge of a given field. No direct application of the results is intended.

Within each of these categories, one could define an implementation target for procurement research; that is,

a study could be driving toward evaluating an existing policy; that is, a high level decision rule which motivates the procurement process, a procedure which may also be at a relatively high level of the procurement process, but which guides how the policy will be implemented. Or the study could be targeted to the operation, the performance of procurement practitioners in their day-to-day operations.

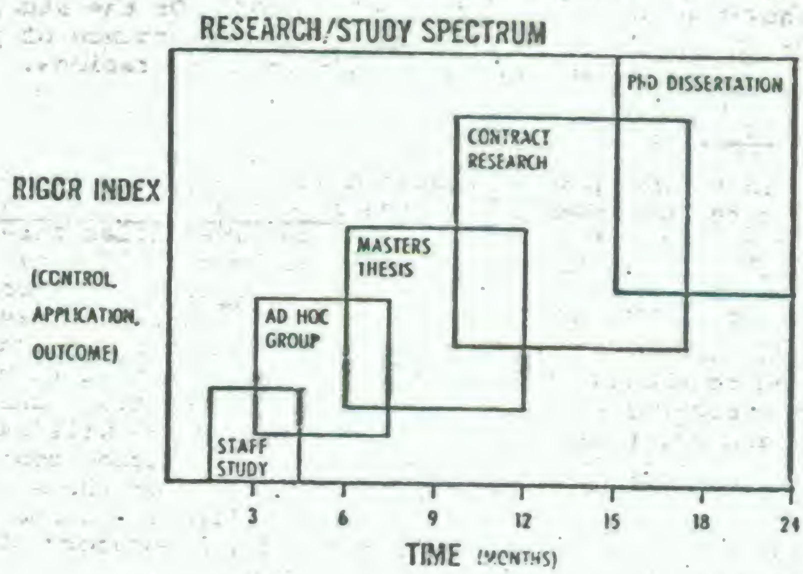
Objectivity of Data

The last dimension of research which may be used to view procurement research, is the objectivity of the data which went into the study. Helmstadter identifies three characteristics of data objectivity as being: library research, field research, or laboratory research. Library research relies heavily upon what other researchers have published in previous studies, learned journals, periodicals, and textbooks. Field research suggests that in many cases the researcher can only control the questions that he may ask and the timing and location in which he will ask those questions. In this case the sampling method controls the objectivity of the data which were used for the study. Laboratory research depends upon controlling input and output parameters. In the field of procurement, laboratory studies would be usually limited to simulation models.

PROCUREMENT RESEARCH TRADE-OFFS

The modes of procurement research, such as the participants, the form of the product; and the dimensions of procurement research such as the breadth of application, the level of outcome, and the objectivity of the data; permits asking the question, from the decision maker's point of view, when can I get results? It also suggests that the initiator or consumer of procurement research may have to make some trade-off between a rigor index which would be composed of combining such factors as the data objectivity, the breadth of application, and the level of outcome desired; against the time frame when he might expect results in one of the research product forms which we have discussed, (Figure 2). This construct can be employed by the decision maker who knows he needs procurement research to support his decision, but is faced with the inevitable time constraint in helping him to make the tradeoff between the type of study or research to be conducted and when he might expect to get results.

Figure 2
SPONSOR INTERFACE



PRINCIPLES FOR IMPLEMENTATION

These constructs of modes and dimensions of procurement research suggest that there is no one best way for procurement research. Academic argument might pursue the merits of each dimension and mode; however, this will not help decision makers, researchers, and operators come to grips with the best way to utilize procurement research to generate achievable and long-standing improvements to the procurement process. To that end, there are five principles which we conclude override either dimensions or modes of procurement research.

These principles are:

1. Secure operator and researcher agreement and acceptance of the problem definition and its delimitation,

2. Establish an input knowledge base for the research,

3. Establish an output fact picture,

4. Satisfy customers of procurement research, and

5. Define an implementation tool.

The first principle, securing acceptance and agreement on the problem definition and delimitation, is necessary for both initiator and researcher to establish a common bond and common frame of reference for the project itself. This process is very much analogous to the procurement process itself, where the customer and the producer come to grips with what is being bought and why. Without this essential step, procurement research may take us to the wrong target.

Establishment of the input knowledge base is not unlike the problem solving technique proposed by Kepner and Tregoe in their book, The Rational Manager. We need to know what we know, and we need to know what we don't know. The establishment of the input knowledge base may be a research project itself. However, unless we can establish the historic and present fact picture for what the current problem is, results may be questionable or soft. Without facts on the problem's impact on our measures of merit, we cannot decide where to apply management and research emphasis and resources.

At the conclusion of the research, the output fact picture must be carefully established and quantified, which often involves going back to the input knowledge base. The research results must be defined and presented in the same manner in which the problem was originally defined and the input knowledge base was established. A shifting frame of reference helps neither researcher nor operator.

Keeping customer satisfaction paramount requires strong and frequent interaction between researcher and operator during all steps of the research process and the ability to

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be flexible and to make necessary trade-offs so that the results will be ready when the opportunity for their use arises. The decision maker must be flexible enough to interact with the researcher, to accept redefinition of the problem, and to adjust his expectation level to that which the researcher may be able to produce. The researcher must be flexible enough to adjust methodologies, accept problem redefinitions, and occassionally provide "satisficing" (i.e., good enough for the purpose vs. optimum) responses.

Definition of an implementation tool is the last, and perhaps most significant, principle which must be borne in mind. When procurement research is undertaken with the objective of securing implementation, the researcher and the initiator must mutually determine the most practical and effective way to implement the research results. Will implementation consist of a regulation, a directive, a computer program, or a training program? Who will be affected and in what manner? If an implementation tool has not been defined, then the results may sit idle on the shelves of the library or in the lower left-hand desk drawer.

CONCLUSION

We have presented in this paper a construct of modes and dimensions designed to clarify the many forms taken by procurement research. Employing the construct, the paper addressed the question, procurement research--is there one best way?, by offering the answer: "it all depends on what mode and dimension the problem, and the appropriate research plan, presents to management and researcher alike." Only in the context of the problem and its environment can we decide on the best way for procurement research to proceed.

SELECTED REFERENCES

Helmstadter, A. C. Research Concepts in Human Behavior. Appleton, Century, Crofts

Kepner, Charles H. and Benjamin B. Tregoe. The Rational Manager. McGraw-Hill.

Martin, M. Dean, Gerald R. J. Heuer, John C. Kingston, and Eddie L. Williams. A Proposed Definition and Taxonomy for Procurement Research in the Department of Defense. Air Force Institute of Technology, School of Systems and Logistics, SLSR 12-77B.

SYSTEMS ACQUISITION

A SYSTEMS DYNAMICS APPROACH TO UNDERSTANDING COST, PERFORMANCE, AND SCHEDULE CHANGE INTERACTIONS IN THE WEAPON SYSTEM ACQUISITION CONTROL PROCESS

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Dr. Peter Gardiner
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Social Sciences Research Institute
University of Southern California

Introduction

If one studies modern industrial processes, concentrating particularly on those which include frequent changes in goals, budget "rollercoastering," and a high degree of design and production complexity, he finds few that compare with the acquisition of major military systems. It is certainly doubtful whether any organization or industry faces more baffling, frustrating challenges than those encountered routinely by DOD (and associated industry) scientists, engineers, technicians and managers; they contend almost daily with schedule slides, performance failures and dollar escalation.

The dollar amounts are substantial. The USAF FY 78 and FY 79 RDT&E[1] requests for general purpose forces were 964.5 million and 980.8 million respectively.[2] The requests (same years) of the three services for Strategic Forces were 1.454 billion and 2.077 billion respectively.[3] The Navy listed aircraft Program Acquisition costs of 2.204 billion in FY 1977, while the Army showed 1.748 billion in FY 1976 for Aircraft Missiles, Tracked Combat Vehicles and other.[4]

However, the size of the investment, even if described in terms of scarce dollars, irretrievable time or wasted efforts of thousands of dedicated individuals, is not the crucial element; while size does contribute, the fundamental reason for the management, technical and economic difficulties is change--change in unit performance (actual, estimated and desired), change in system goals, change in budget authority and change in quantities desired. The Aerospace Daily of February 24, 1977, carried these items:

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[1] RDT&E - Research, Development, Test and Evaluation.

[2] Aerospace Daily, February 24, 1977, Page 293.

[3] Aerospace Daily, January 19, 1977, Pages 98-99.

[4] Ibid.

". . . the 60 Minuteman II missiles covered by the Ford Administration supplemental request will not be built and the FY '77 funds will be used instead for spares."

". . . The B-1 program was cut 280 million in FY '78 -- from $2.15 billion to $1.87 billion--and, as expected, the number of bombers to be procured fell from eight to five."

". . . F-15 production was cut back from a rate of 108 a year to 78. The $334 million resulting saving would be applied to the original $1.76 billion request to bring it down to $1.43 billion."

"The Sikorsky CH-53 helicopter for the Navy and Marine Corps was also cut by $62 million (out of an original $87 million request) as part of a move to stretch out the program by a year."

"The Army's AAH was cut in half--from $200 million to $100 million--reflecting what DOD called (Secretary of Defense) Brown more specifically identified as a concern over the helicopter's vulnerability."

"In the shipbuilding area, the Aegis-equipped CSGN was knocked out entirely for a $187 million reduction while another $43 million was deleted for conversion of an LST to a PHM. The PHM program will be further reviewed."

There are many, many more examples available, should one choose to focus on funding increases or performance upgrading or schedule stretchouts.

Obviously, changes cause problems. The next question an interested taxpayer might ask is, "Why are there so many changes?" The question itself betrays a lack of understanding as to how the process functions. The person asking the question is not aware of the "soft" base of intelligence information underlying many of the proposed system requirements; he isn't familiar with the political environment in which Congressmen must criticze DOD management while at the same time demanding that programs be awarded to companies in their home states or districts; and he's certainly not aware of the intricacies surrounding and pervading the integration of sophisticated missiles, aircraft and computers. In attempting to make the point convincingly, that the questioner does not understand the acquisition process, we would be guilty of overkill were we to also mention the pitfalls of necessarily attempting always to advance the state-of-the-art against a formidable, aggressive, potential adversary.

And yet, to be fair, being able to answer those (and similar) questions is one thing; being able to explain how the total process works is another. In fact, it would probably be honest to admit that few people within the system really understand how--and why-- the entire system functions as it does. Most probably realize that the resource of dollars is not limitless; therefore, priorities must be established. They also understand that, if unforeseen critical obstacles crop up in a high priority program, other lesser priority programs may face large budget cuts. Most military and civilian managers may appreciate that cost estimating is an art (not a science) at best and is subject to human error. It shouldn't be unexpected, therefore, that unexpectedly high inflation, supply and demand factors, and technological uncertainty can cause total estimated program costs at completion to surpass early estimates by 10, 100, or even 300 percent.

These and other perturbations of the environment do not surprise the experts. They realize that what they (the experts and practitioners, that is) need are tools or techniques or "rules of thumb" that will enable them to assess more accurately the impact of changes which they know will surely come. For example, what will be the impact upon a production program if funds are cut by $10 million or $100 million? How will a 10% increase in workers' wages impact upon quantities to be produced? What should be the expected dollar return (to DOD) if a production schedule is stretched out and monthly deliveries reduced? If system performance goals are increased, how many additional units must be procured - or should we reduce the total quantity while increasing the unit performance of each item remaining to be built?

Objective

The objective of this paper is to propose one way of developing a systematic understanding of the Weapons Acquisition Process, that of model building and computer simulation. A computer simulation and modeling approach, such as we propose, may permit managers such as SPO's, the user command requirements elements, military department staff agencies, or contractor corporate headquarters, to answer such questions from within their own resources; the model is, in effect, a planning tool to be used to simulate the impacts of proposed changes.

The remaining parts of this paper briefly describe simulation and our approach to it (System Dynamics), explain the rather "simple-minded" but illustrative model we have chosen to demonstrate how this approach could be applied to the weapon system procurement process, indicate how such a model can be used to gain insight into how changes affect the system, and discuss how our model could be expanded and enhanced to suit a real weapon system, and suggest - in our conclusion - potential uses of such expanded applications.

Methodology

Our approach in this paper is that of simulation, and, more specifically, a version of simulation called system dynamics. Simulation has been around a long time and modelers who use simulation have generally followed a two step process. First, they construct a model of some system of interest to them in order to imitate the system's behavior. If the model can successfully imitate the system's behavior under a wide range of circumstances, the modeler will feel confident enough to move on to the second step: running policy experiments. In this step the modeler alters particular inputs to the model that correspond to real world policy options. For example, the Congress could cut the budget of a program by 20%. By interpreting the model's responses to the changes, the modeler hopes to understand how the real system would respond to the same policy changes. Once a model has been developed and confidence has been gained in its utility, the modeler can make his model available to interested users (for example, a SPO if the model is one of a system for which the SPO has responsibility). The user then can test out real system reactions to policy changes using his model of the real system as a surrogate for it.

In physical systems, simulations are relatively common and run the gamut from simple hand simulations with table top models and physical mock-ups to more recent and exotic mathematical models and computer simulations such as those used to control space flights.

In biological systems, experts are now at work constructing computer based simulation models of kidneys, cardiovascular systems, and so on, to test new medical policies. In social systems (and the weapon procurement system is a social system), especially over the past decade, there has been a great increase in the resources allocated to building interdisciplinary computer simulation models of complex social systems. In each area of application the process is the same. A model is constructed and then "tweaked" to see what kinds of responses are produced.

With the advent of large digital computers, modelers have turned increasingly to developing models of complex systems that are programmable on digital computers. In fact, most current simulation efforts depend heavily upon the use of a computer to assist in manipulating the otherwise unwieldy mass of data and interrelationships that have to be considered. We should stress that using a computer does not, per se, lend any particular authority or correctness to an analysis. The computer is merely a very fast, very accurate, electrical idiot that manipulates data according to the framework and ground rules established by the model. Should the computer output fail to accurately initiate the behavior of the real system, the <u>model</u> and the modeler (not the computer) are to blame.

While the advent of bigger and faster computers has helped the modeler to manipulate larger bodies of information, better computers are not the main reason for the growing use of simulation models. Rather, the growth in the complexity of the systems we are called upon to manage and the increasing need for an inexpensive means to test out policies prior to implementation have been the main stimulants. No engineer would dream of trying to analyze and predict the behavior of complex physical systems (such as those used in space flight control) by inspection, thinking a lot, debate, compromise, and seat-of-the-pants intuition. Instead, engineers turn to laboratory prototypes and computer simulation to test policies out <u>before</u> the very expensive rocket is launched. Yet we expect SPO's to manage weapon system procurement involving systems that are at least an order of magnitude more complex than purely physical systems and to make their policy judgments by the more accustomed art of debate, compromise, and so on. The results are clear. One need only read in the daily papers about cost overruns, schedule delays, and the like.

It is, of course, unfair to say that SPO's, like managers of most social systems, do not make use of models. Every time an SPO looks at a PERT chart, a scale model of a new weapon system, or a blueprint of a new system component, he is using a substitute for the real system. These physical and pictorial models are similar to the mathematical models used in computer simulations in that they provide explicit substitutes for the real system. Yet these models represent physical subsystems and they are static. Most of the interesting (and least understood) aspects of weapon procurement systems come from the dynamic interactions over time of its physical and social component parts. PERT charts, blueprints, and scale models cannot help SPO's (or anyone else) project the procurement system behavior over time. So they turn to two other kinds of models. In most instances SPO's are forced to turn to fuzzy, qualitative, chameleon-like mental models to serve as substitutes for the real system. In a growing number of instances, however, SPO's are trying to turn to explicit, quantitative, mathematical models. These models span the fields of econometrics, operations research, management science, and applied mathematics and have been used to study physical, biological, and social systems. While our comments in this paper are general and can be applied to any weapon process procurement system or any phase of it (e.g. planning or control), our particular example in this paper focuses on the planning phase of weapon procurement. We therefore focus our discussion on one approach, that of system dynamics, to building computer simulation models of that phase.

System Dynamics

System dynamics was developed during the 1950's by Jay W. Forrester and his colleagues at the Massachusetts Institute of Technology to help in their study of industrial systems (Forrester 1961). Over the past decade, the technique has been widely applied to simulate a variety of social systems: the world copper market (Ballmer, 1960), natural resource use (Behrens, 1973), planning and control for community hospitals (Masson, Moody, and Stubbs, 1972), decay of urban systems (Forrester, 1969), the US energy system (Naill, 1975), regulation of electric utilities (Ford, 1976), and logistics systems (Stanhagen and Gardiner, 1976). The technique is most widely known for its use in the study of The Limits to Growth in population and industrial activity in a finite world (Meadows et al., 1972).

The heart of the system dynamics paradigm is the view that social systems belong to a general class of nonlinear, feedback systems. To facilitate the representation of such systems, the system dynamics technique allows for easy representation of nonlinear relationships and chains of relationships that close on themselves to form feedback loops. It is in the interlocking structure of multiple feedback loops that the system dynamics practitioner seeks to find the explanation of the dynamic behavior of complex social systems:

> It is in the positive feedback form of system structure that one finds the forces of growth. It is the negative feedback, or goal-seeking, structure of systems that one finds the causes of fluctuation and instability.
>
> (Forrester, 1968)

To build a system dynamics model, one follows a series of steps described in the preface to the Dynamics of Growth in a Finite World (Meadows, 1974) or those discussed in the Introduction to Urban Dynamics (Alfeld and Graham, 1976). Generally, the following steps are required:

Step 1. State the Problem. At the very beginning, the modeler should specify the issues the model is to address. Usually this involves a description of a particular system that is behaving "poorly" and a question of which policy proposals should be adopted to make the system behave "better" in the future.

Step 2. Determine the Key Factors and Their Causal Interrelationships. In this step, the modeler lists the key factors that are believed to cause the behavior of concern. The interrelationships among these factors are identified and portrayed in the form of causal diagrams. An example of a causal diagram in the weapon procurement system is given in Figure 1. As the numerous interrelationships in any system are identified, some series of relationships form a closed chain or feedback loop. In Figure 1, such a loop is noted by a . It is in the interaction of these loops, that the modelers seek to explain the behavior of the system under study.

Step 3. Formulate Model in Flow Diagram. In this step the representation of the system is reformulated in the form of a flow diagram which facilitates the eventual representation in the form of a set of difference equations. The flow diagram is especially helpful in distinguishing between flows of material and flows of information. Moreover, the flow diagram forces the modeler to indicate explicitly any delays or nonlinear relationships included in the model.

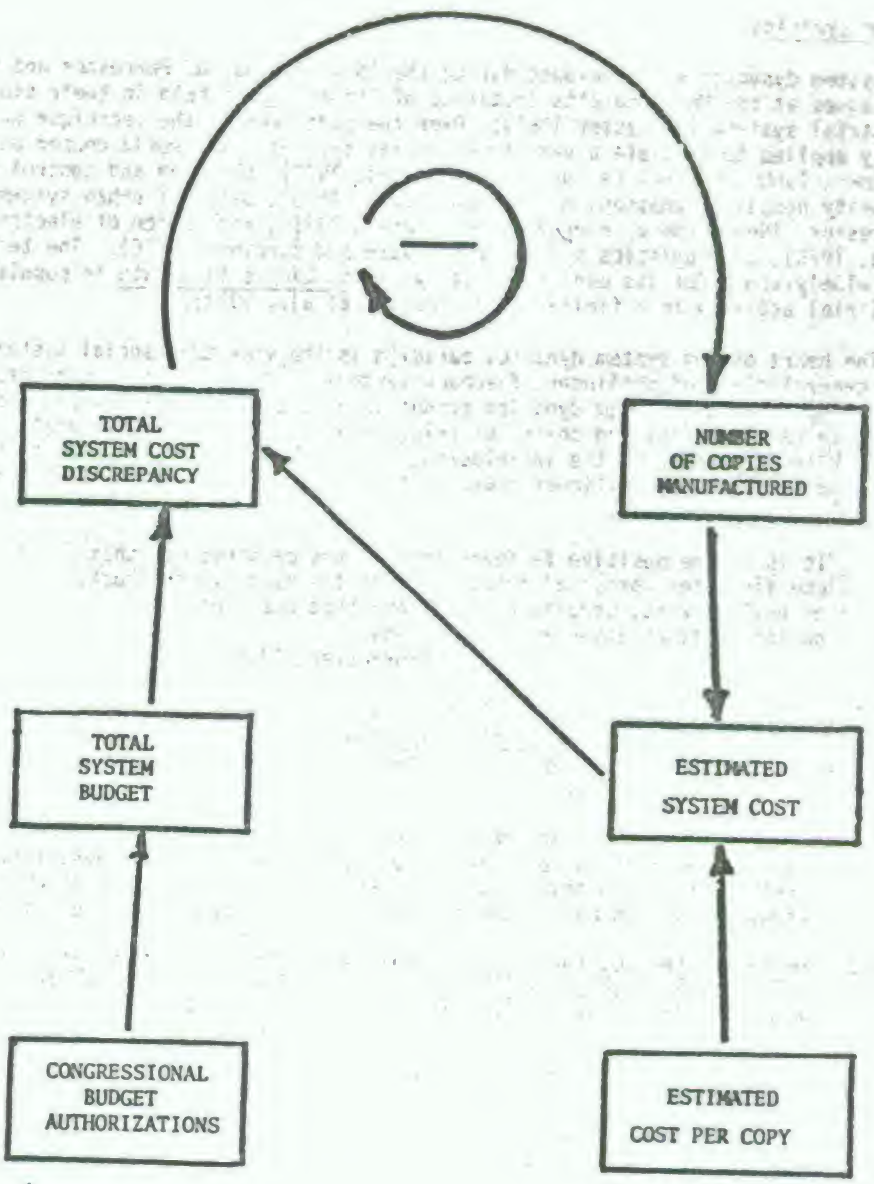


Figure 1. AN ILLUSTRATION OF A (NEGATIVE) FEEDBACK LOOP IN THE WEAPON SYSTEM ACQUISITION CONTROL PROCESS

The use of causal loop diagrams and flow diagrams not only helps the modeler to keep track of his progress, but it helps communicate the important features of the model to potential users as well. The use of meaningful variable names--names that can be seen, "felt", or talked about--together with the diagraming aids, gives properly constructed system dynamics models a good chance of bridging the communication barrier between the model builder and model user. This barrier has been described by Goldie (1970) as follows:

> When we attempt to use the new techniques that management scientists advocate, we suddenly find that we are out of the loop. A bright young man takes my problem away and translates it from managerese to computerese.

In speaking about this opportunity for bridging the communication barrier, users often refer to the system dynamics approach as "common sense quantified" whereas more elaborate techniques are described as "common sense made difficult."

Step 4. Estimate the Parameters of the Model. In this step the parameter values must be estimated. Each of the parameters of a system dynamics model is estimated individually from the best information available. This information can take the form of highly accurate physical measurements and make use of volumes of hard statistical data (at one end of the spectrum) or exert opinion and individual intuition (at the other). The use of expert opinion in the absence of more formal data to help in parameter identification tends to make some data purists squirm; yet to rule out subjective inputs if they are the only source of information available ignores the fact that most of the relevant data in any real social system is contained in the heads of people and is not neatly recorded in the form of time series or cross sectional data. Practitioners of other modeling techniques prefer to ignore relationships for which hard statistical data is not available. Leaving such relationships out, however, results in assigning them the parameter value that most people would agree is wrong: zero. By incorporating subjective judgments in estimating parameter values, the system dynamics practitioner can determine through sensitivity testing those areas where further debate and data collection is warranted. If a model's behavior is generally insensitive to certain parameter values, scarce resources should not be wasted in collecting data to estimate them.

Step 5. Generate Initial Output and Increase Confidence in the Model. Once parameter values have been estimated, DYNAMO equations of a system dynamics model can be easily constructed. (DYNAMO is the software package usually used to construct and test system dynamics models.) If the initial output generated by the model fails to imitate the real system's behavior well enough the modeler returns to Step 2 and begins an interactive process. We should emphasize that system dynamics models do not automatically reproduce historical trends since model parameters are estimated individually. This procedure is quite different from modeling approaches wherein model parameters are estimated "all at once" to give the best fit to historical trends over a certain period of time. Thus, it should come as no surprise that such models are capable of providing extremely close fits to historical trends over the time period used in the parameter estimation. They are designed to:

Generating a reasonable pattern of behavior - both over some historical

period and into the future - is but one of several tests that should be performed to increase confidence in a model. Sensitivity testing should be performed to ensure that the model does not respond unrealistically to changes in particular input values. The response of a model to disturbances in exogenous inputs should be examined for plausibility. These and other confidence tests are described in Forrester's Industrial Dynamics (Forrester, 1961).

Step 6. Simulate the Effects of Proposed Changes. In this final step, the modeler simulates the effects of pending or actual changes to determine the effect on the system.

There are at least two kinds of changes that can effect system behavior. First, there are policy changes that are under the control of the SPO. For example, an SPO may be considering the merits of giving a go-ahead on stretching the production schedule vis-a-vis simply slipping the entire schedule by a uniform amount. A second kind of change is one imposed on the system from the outside. For example, a wage increase for production workers, a rise in the cost of material used in construction, or congressional changes in the authorized budget for the program. In these instances there are two questions to be asked: (1) what is the effect of the change on the system if I (the SPO) do nothing? and (2) what action can I take as the system manager in the face of this change to improve system response to it? In Step 6 each kind of change, as well as combinations of changes, are examined.

A Widget System Acquisition

We have chosen to illustrate our approach with the acquisition process surrounding a piece of well-known military hardware: the widget. In this instance widgets are "lumps" of material that normally weigh about one pound each. We have chosen this very simple system to illustrate our approach so that the approach can be focused on, not the details of a very complicated weapon system. Figure 2 shows the various kinds of changes that could be examined in any acquisition process and represents in tree diagram form the shopping list of potential questions that might be asked. To illustrate our approach and keep the task (and presentation) manageable, we have further focused on the budget changes branch in constructing our system dynamics simulation model. Our model, in its current version, does have limited capability to explore other kinds of changes but could easily be expanded to include the system structure capable of answering the questions suggested by the other branches in Figure 2.

Moreover, it would have been possible alternatively to focus on system performance, schedule, unit performance (performance per copy) or even all four. We should note at this point that the tree diagram in Figure 2 (as well as our model) strongly suggest that there are many combinations of changes that are not possible. For example, a commonly desired set of changes that face many SPO's is for more performance per copy, shorter schedule of production, and lower costs per copy that lead to lower system costs (total buy), more copies in the system, higher system performance, and early delivery!*

*See Figure 3 for the causal loop diagram that describes the total system.

- system changes
  - budget changes
    - system performance
    - number of copies
    - schedule
    - performance per copy
  - system performance changes
    - schedule
    - number of copies
    - budget changes
    - performance per copies
  - schedule changes
    - number of copies
    - system performance
    - performance per copy
    - budget
  - performance per copy changes
    - budget
    - system performance
    - number of copies
    - schedule

Figure 2. Tree diagram of possible acquisition system changes.

There is also an important technical point about our model. The printout over time is artificially linked to the time dimension. What this means is that in a larger version of the model, the calculations that now appear over time would probably all be done in one solution interval increment (i.e., one unit of time). However, so that we could watch the model hunt around for the correct response to changes we introduced, we have a model that corresponds more closely to a very patient SPO with a hand calculator making a series of hand calculations over and over again converging on the final and new "steady state" of the system in response to changes introduced.

In a larger and more enhanced version, this "watching a model converge" is of little interest other than to get a feel for how the model functions, so the entire model presented here would be a component of a larger, more realistic and time based model.

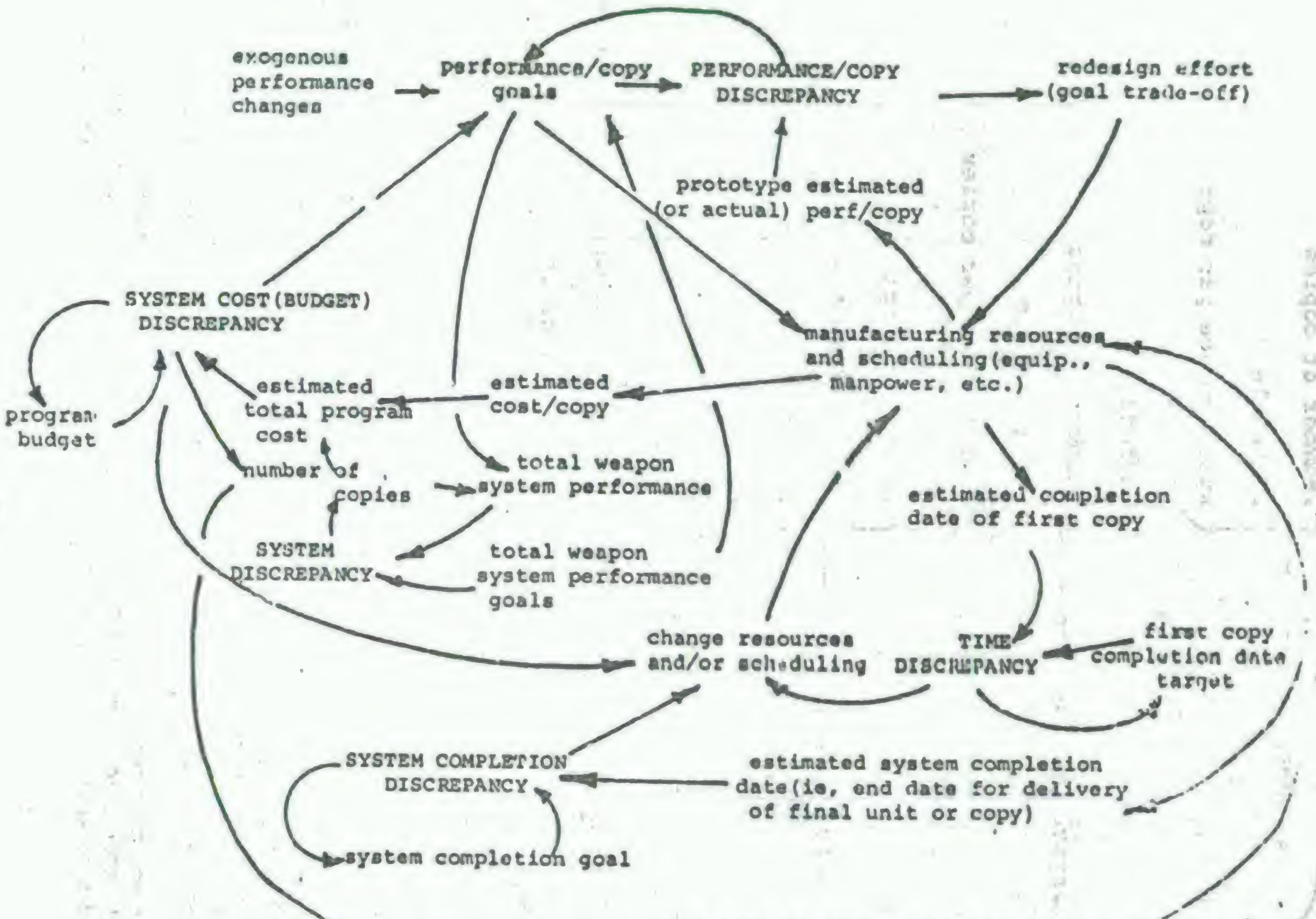


Figure 3. Causal Loop Diagram for Basic Cost, Scheduling and Performance Interactions in Systems Acquisition

It was assumed in constructing our model that the widget program included an RDT&E phase - totally completed for all practical purposes - and a production phase, not yet started. Using the model as a planning tool, we monitor budget discrepancy (program budget compared to estimated program costs, which includes a fixed RDT&E (amount), number of hours discrepancy (total straight time hours required versus total straight time hours available), and system performance discrepancy (compared system performance goals with actual system performance). Also included is a copies change rate, performance per copy change rate, actual system performance change rate and number of days for schedule change rate.

There are no system delays included in the model in this first configuration. However, delays (allowing for the DSARC decision process, for example) could easily be added. Figures 4, 5 and 6 portray the schedule (HDISC), cost (BDISC) and performance (SPERFD) sub-models; Figure 7 is the total model. Appendix A defines all terms, including fixed values and table functions. Appendix B is the program statements.

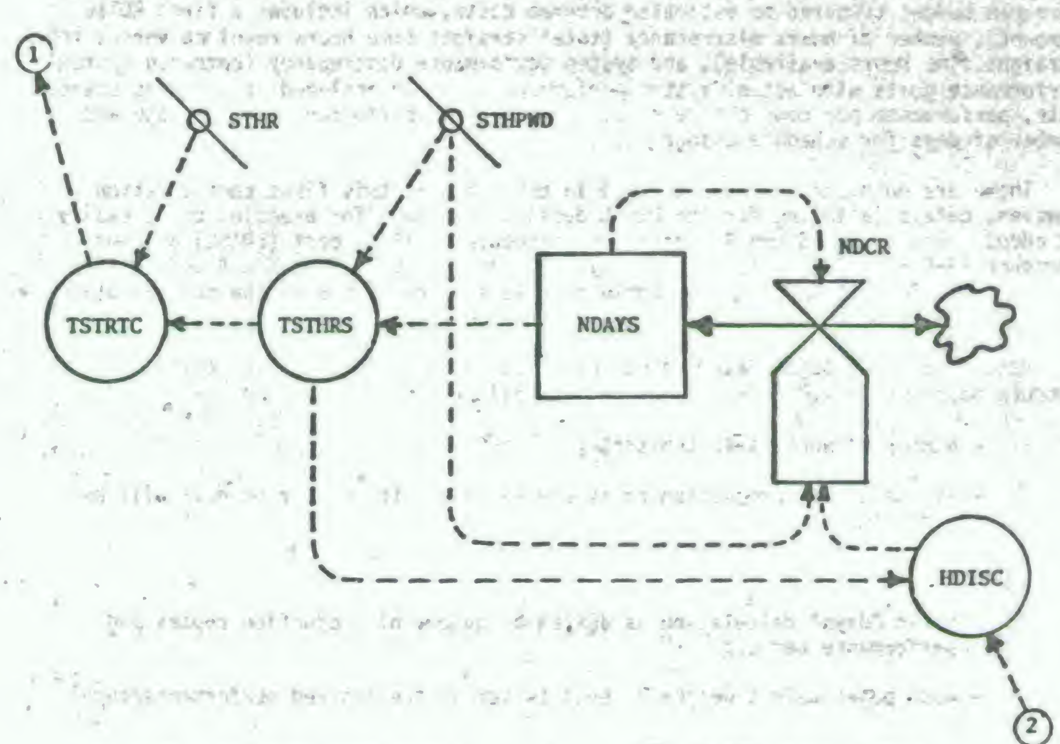
Assumptions and basis fixed values were set for a system that is scheduled to produce paper weights.[5] Assumptions are as follows:

- number of workers is constant
- if additional production hours are required, the number of days will be increased
- overtime will not be used
- basic "days" calculation is driven by number of production copies and performance per copy
- each paper weight weighs 1 pound (which is the desired performance/copy)

[5]Following design and check-out of the DYNAMO model, it can be expanded to fit more complicated products such as aircraft or missiles.

*In an enhanced version any or all of these assumptions could be relaxed as necessary to reflect the real system.

FIGURE 4. HDISC (NUMBER OF HOURS DISCREPANCY)



1. STHR - STRAIGHT TIME HOURLY WAGE RATE
2. TSTRTC - TOTAL STRAIGHT TIME COSTS
3. TSTHRS - TOTAL NUMBER OF STRAIGHT TIME HOURS
4. STHPWD - NUMBER OF HOURS PER WORKER PER DAY
5. NDAYS - NUMBER OF DAYS SCHEDULED
6. NDCR - NUMBER OF DAYS FOR SCHEDULE CHANGE
7. HDISC - NUMBER OF HOURS DISCREPANCY

1 - LABTC TOTAL COST OF LABOR

2 - TSTHRR TOTAL STRAIGHT TIME HOURS REQUIRED

FIGURE 5. BDISC(BUDGET DISCREPANCY)

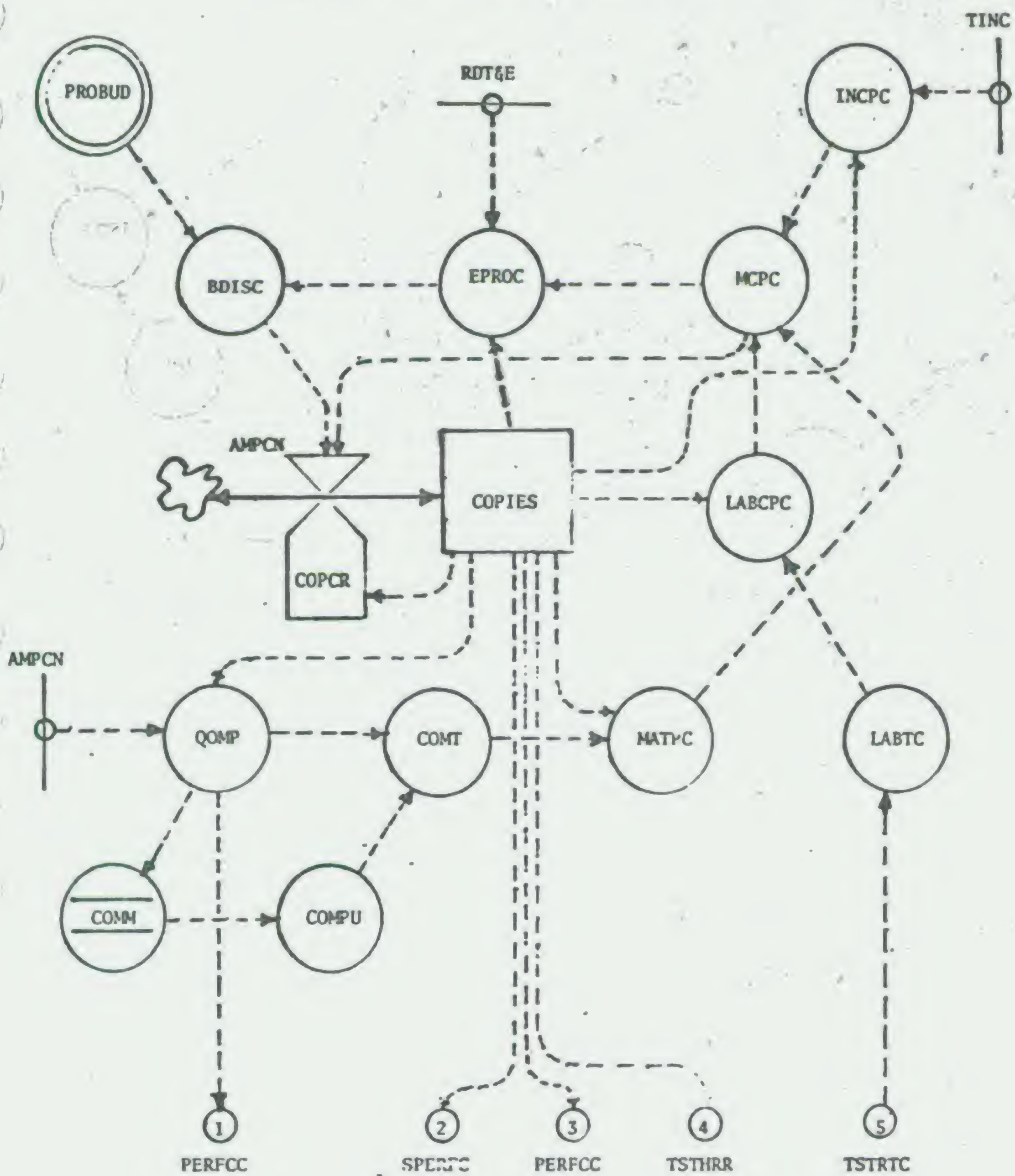
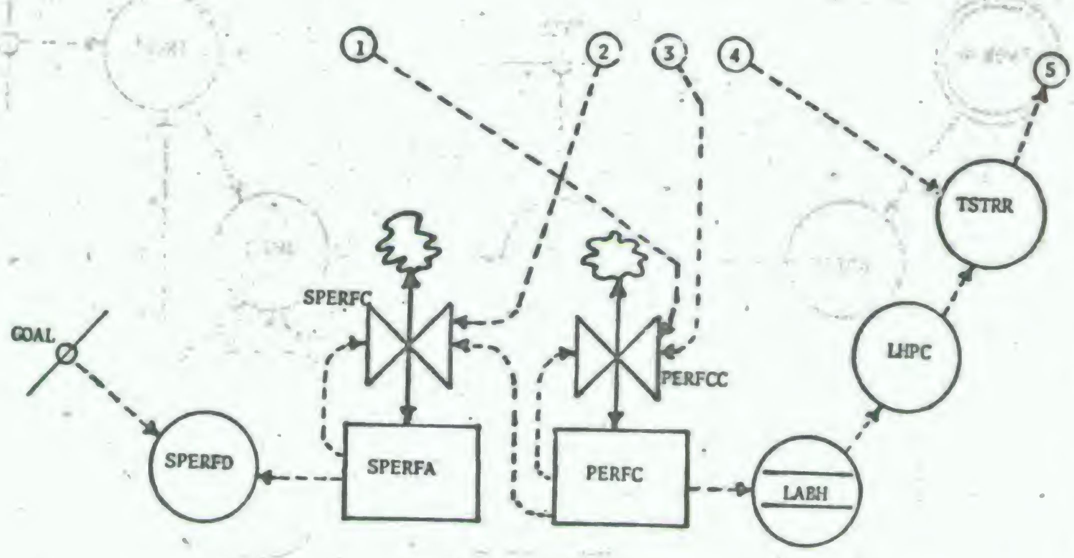


FIGURE 6. SPERFD (SYSTEM PERFORMANCE DISCREPANCY)



1. GOAL - SYSTEM PERFORMANCE GOAL
2. SPERFD - SYSTEM PERFORMANCE DISCREPANCY
3. SPERFC - ACTUAL SYSTEM PERFORMANCE CHANGE RATE
4. SPERFA - ACTUAL SYSTEM PERFORMANCE
5. PERFCC - PERFORMANCE PER COPY CHANGE RATE
6. PERFPC - PERFORMANCE PER COPY
7. LABH - LABOR HOURS TABLE FUNCTION
8. LHPC - LABOR HOURS PER COPY
9. TSTHRR - TOTAL STRAIGHT TIME HOURS REQUIRED

1 - QOMP - QUANTITY OF MATERIAL PURCHASED

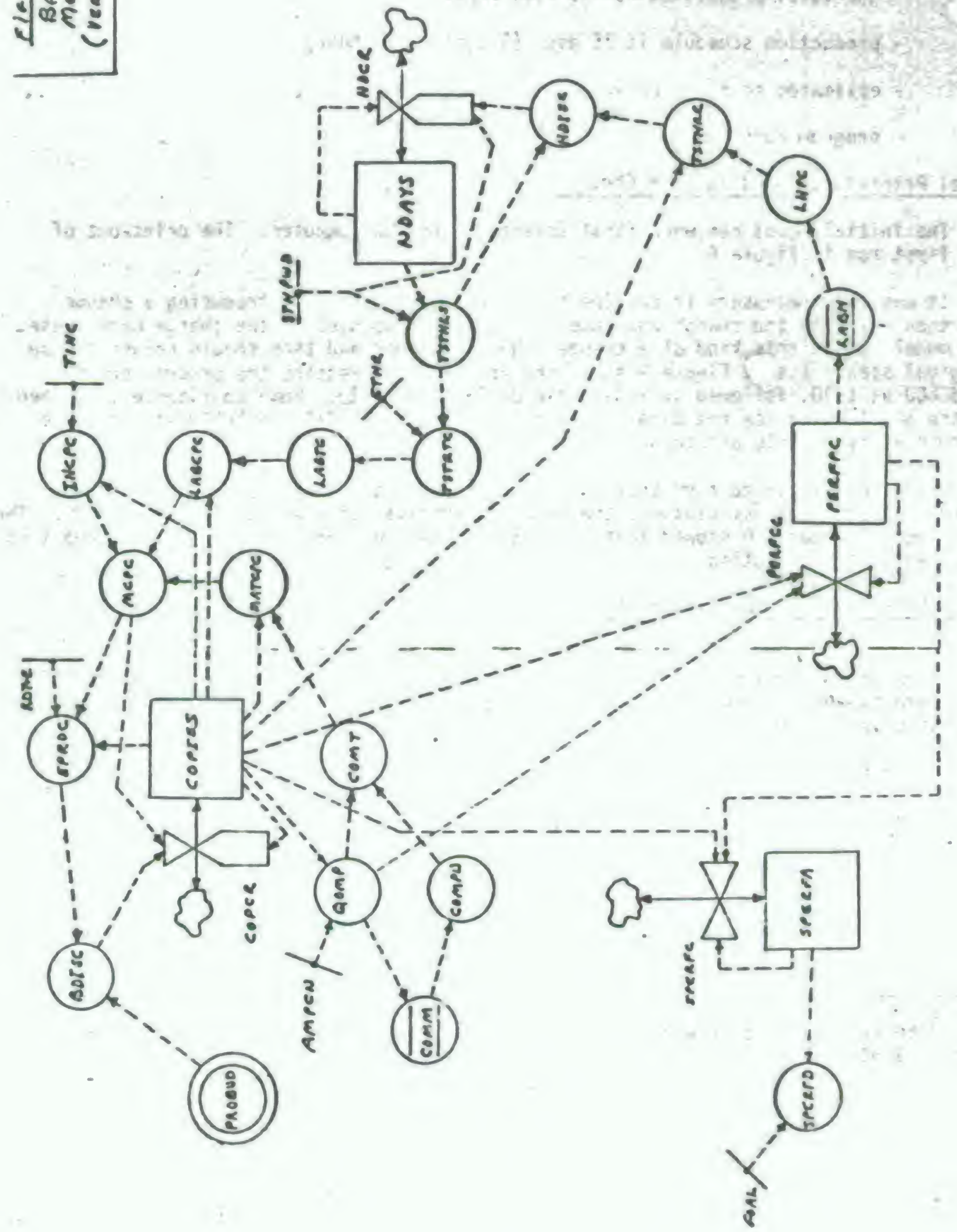
2 - COPIES - NUMBER OF COPIES BEING PROCURED

3 - COPIES - NUMBER OF COPIES BEING PROCURED

4 - COPIES - SAME AS ABOVE

5 - HDISC - NUMBER OF HOURS DISCREPANCY

FIGURE 7
BASIC
MODEL
(VERSION 1)



- the total production run is 1000 copies

- production schedule is 25 days (5 copies per hour)

- estimated cost per copy is $10

- program budget is $10,000

Model Print-outs; Verification Checks

The initial model ran when first inserted into the computer. The print-out of the first run is Figure 8.

It was then necessary to examine the model's validity by introducing a change and then removing the change and observing if the responses to the change made sense. The model, given this kind of a change, should respond and then should return to the original steady state. Figure 9 shows the effect of increasing the program budget by $2000 at t=10, followed by a decrease of $2000 at t=20. Some confidence is gained in the model as we see the data (copies=C, N days=N, EPDC=R and PROBUD=*) increase appropriately at t=10 and then return to normal after the decrease at t=20.

Additionally, to confirm that the solution was not an artifact of the solution interval used in the simulation, the solution interval of 1 was dropped to .03125. The print-out in Figure 10 showed that the change affected transients but had no impact on the steady state solution.

Model Print-outs - Charging Inputs

At this stage in the simulation design, there is no capability to input a change to system performance goals, program schedule or performance per copy.[6] The model only permits showing the impact of a program budget change or of changing the following variables:

1) PROBUD (Program Budget)

2) LABH (estimate of Labor Hours per Copy as a function of Performance per Copy)

---

[6] The capability to change these factors can be provided in a later version of the simulation.

FIGURE 8A. TEST RUN(H=-1000,T=10 DAYS,H=-2000,T=25 DAYS)

SYSTEM ACQUISITION MODEL 5/21/77 BASIC RUN

TIME E+00	COPIES E+00	BDISC E+00	SPERFD E+00	HDISC E+00	MCPC E+00	LABCPC E+00	MATCPC E+00	INCPC E+00	NDAYS E+00
.0	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
1.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
2.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
3.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
4.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
5.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
6.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
7.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
8.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
9.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
10.	1000.0	-1000.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
11.	888.9	-864.2	.00	-22.222	9.000	5.0000	3.0000	1.0000	25.000
12.	802.2	-168.4	111.11	-17.332	9.972	5.6250	3.2222	1.1250	25.000
13.	785.7	295.0	197.77	-3.309	10.182	5.5401	3.3955	1.2465	22.222
14.	815.8	323.7	214.31	6.017	9.807	5.1053	3.4286	1.2728	20.056
15.	850.2	115.9	184.23	6.880	9.410	4.8156	3.3685	1.2258	19.642
16.	862.7	-75.8	149.83	2.499	9.274	4.7977	3.2997	1.1762	20.394
17.	854.6	-125.6	137.33	-1.619	9.361	4.9276	3.2747	1.1592	21.254
18.	841.4	-63.9	145.43	-2.642	9.508	5.0474	3.2909	1.1702	21.567
19.	834.7	13.2	158.64	-1.333	9.584	5.0785	3.3173	1.1885	21.364
20.	836.1	44.2	165.30	.275	9.569	5.0399	3.3306	1.1980	21.034
21.	840.7	29.7	163.93	.929	9.516	4.9918	3.3279	1.1961	20.867
22.	843.8	1.3	159.28	.626	9.480	4.9724	3.3186	1.1895	20.902
23.	844.0	-14.5	156.15	.028	9.479	4.9815	3.3123	1.1851	21.018
24.	842.5	-12.8	156.01	-.306	9.496	4.9992	3.3120	1.1848	21.096
25.	841.1	-2002.9	157.54	-.268	9.511	5.0091	3.3151	1.1870	21.100
26.	630.6	-1563.3	158.88	-42.102	9.515	5.0080	3.3178	1.1889	21.061
27.	500.3	-153.8	369.39	-26.068	11.994	6.6691	3.7388	1.5858	21.028
28.	487.8	547.6	499.73	-2.501	12.301	6.3027	3.9995	1.9989	15.765
29.	536.8	453.7	512.24	9.798	11.178	5.1282	4.0000	2.0502	12.507
30.	580.7	87.3	463.25	8.781	10.333	4.5436	3.9265	1.8631	12.194
					10.183	4.6220	3.8387	1.7222	13.419

FIGURE 8B. TEST RUN(H=$1000,T=10 DAYS;$H_1$=-$2000,T_1=25 DAYS)

F SYSTEM ACQUISITION MODEL . 5/21/77 BASIC RUN

COPIES=C,NDAYS=N,EPROC=$,PROBUD=*

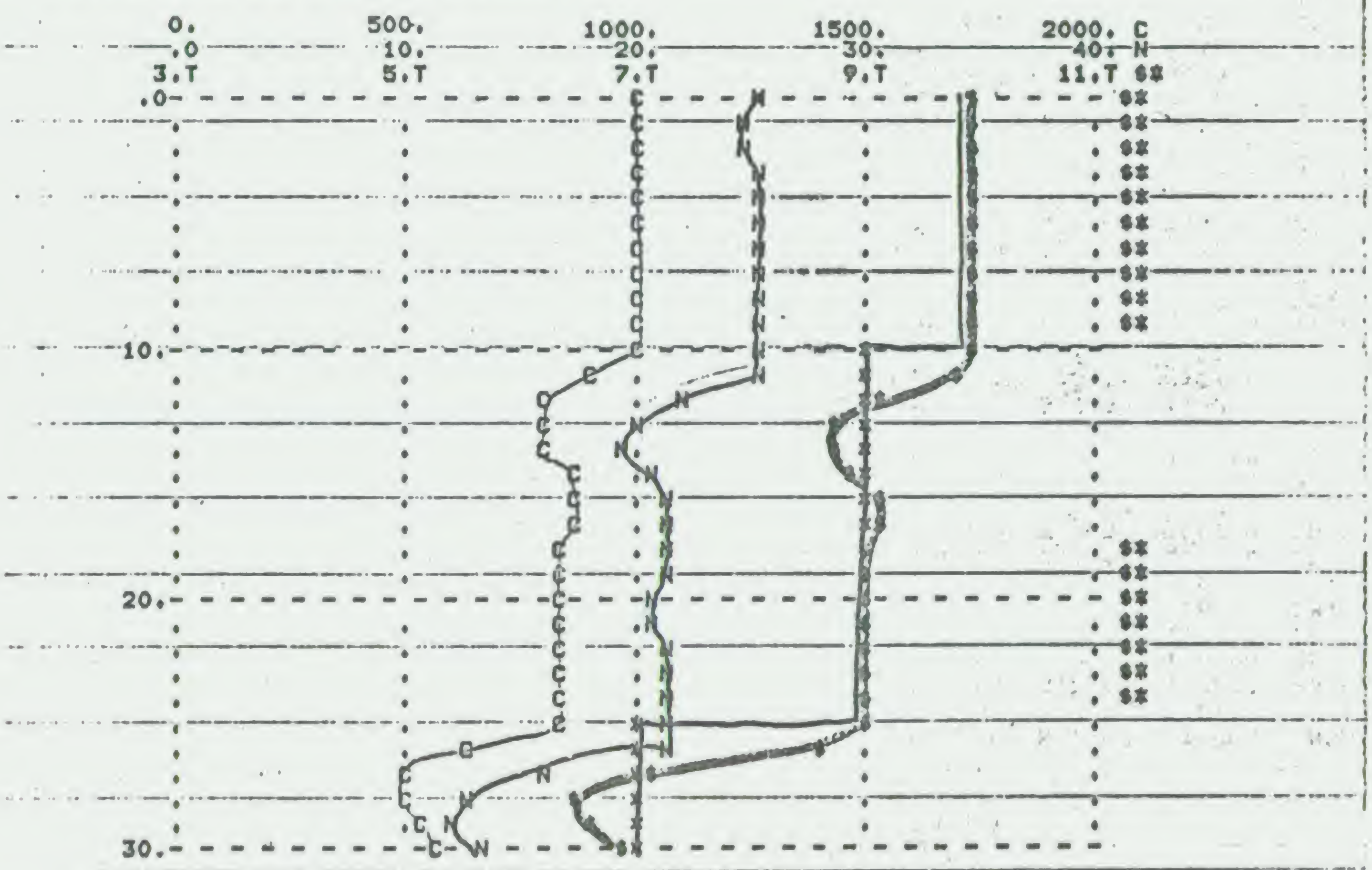


Figure 8-C —SYSTEM-ACQUISITION MODEL— 5/21/77 —BASIC-RUN—

PERFG=G,SPERFA=A

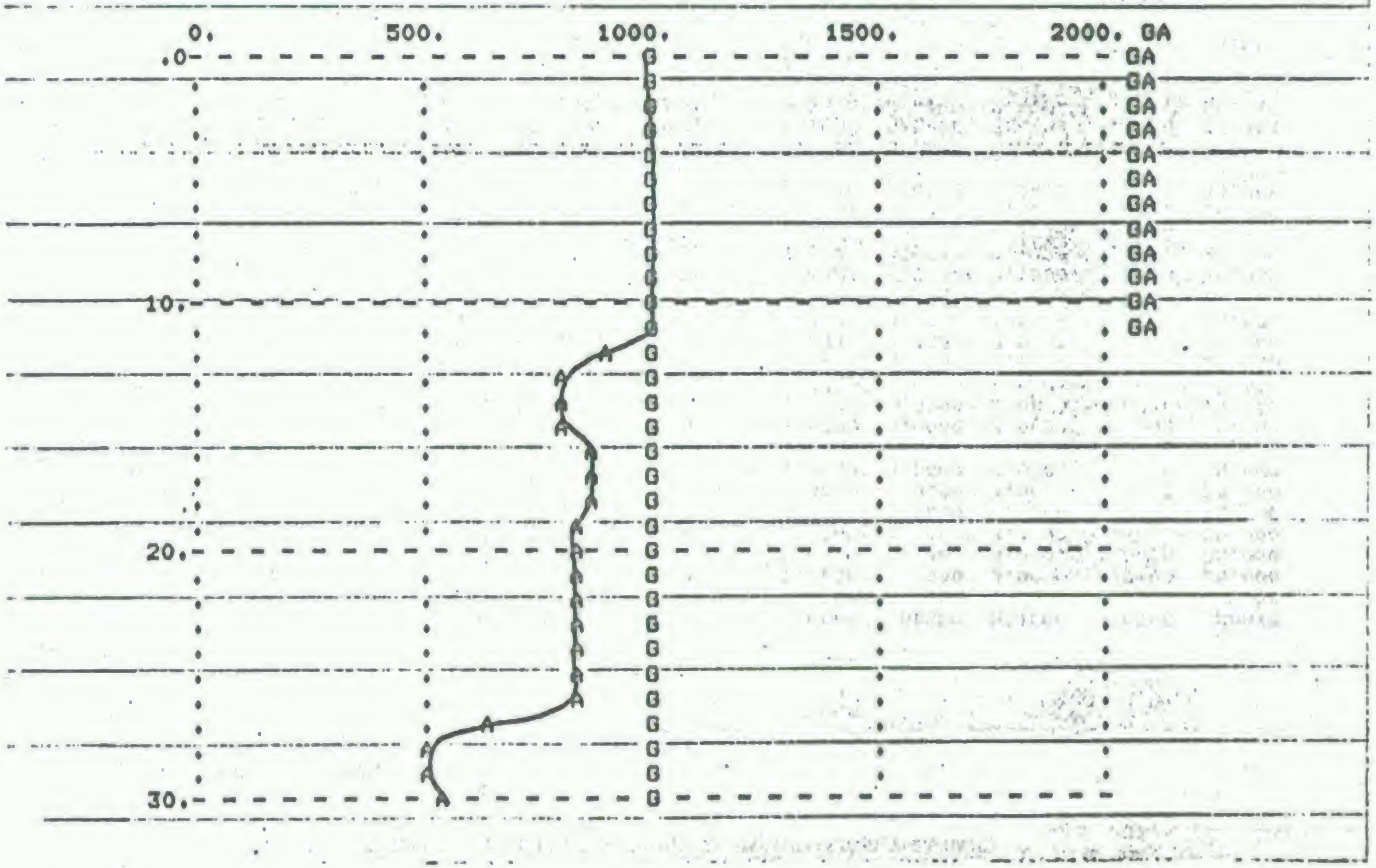


FIGURE 9A. TEST RUN(H=+$2000,T=10 DAYS;H=-$2000,T=20 DAYS)

	H	T1
PRESENT	2000.	20.00
ORIGINAL	-1000.	25.00

SYSTEM-ACQUISITION-MODEL 5/21/77

TIME E+00	COPIES E+00	BDISC E+00	SPERFD E+00	HDISC E+00	MCPC E+00	LABCPC E+00	MATCPC E+00	INCPC E+00	NDAYS E+00
.0	1000.0	.0	.00	.000	9.0000	5.0000	3.0000	1.0000	25.000
1.	1000.0	.0	.00	.000	9.0000	5.0000	3.0000	1.0000	25.000
2.	1000.0	.0	.00	.000	9.0000	5.0000	3.0000	1.0000	25.000
3.	1000.0	.0	.00	.000	9.0000	5.0000	3.0000	1.0000	25.000
4.	1000.0	.0	.00	.000	9.0000	5.0000	3.0000	1.0000	25.000
5.	1000.0	.0	.00	.000	9.0000	5.0000	3.0000	1.0000	25.000
6.	1000.0	.0	.00	.000	9.0000	5.0000	3.0000	1.0000	25.000
7.	1000.0	.0	.00	.000	9.0000	5.0000	3.0000	1.0000	25.000
8.	1000.0	.0	.00	.000	9.0000	5.0000	3.0000	1.0000	25.000
9.	1000.0	.0	.00	.000	9.0000	5.0000	3.0000	1.0000	25.000
10.	1000.0	2000.0	.00	.000	9.0000	5.0000	3.0000	1.0000	25.000
11.	1214.0	1481.0	-79.32	26.930	7.8412	4.4454	2.5721	.8237	26.983
12.	1362.8	782.2	-223.66	27.837	7.4974	4.4893	2.2743	.7338	30.591
13.	1429.5	237.2	-340.46	17.808	7.5291	4.6886	2.1410	.6995	33.511
14.	1438.7	-67.4	-402.73	7.204	7.6924	4.8748	2.1225	.6950	35.068
15.	1422.1	-167.4	-420.33	.355	7.8527	4.9938	2.1558	.7032	35.508
16.	1401.3	-148.1	-413.78	-2.491	7.9554	5.0444	2.1974	.7136	35.344
17.	1386.3	-87.7	-399.98	-2.735	7.9981	5.0493	2.2274	.7213	34.999
18.	1378.9	-32.7	-388.19	-1.866	8.0014	5.0338	2.2423	.7252	34.705
19.	1377.0	.6	-381.35	-.865	7.9879	5.0157	2.2460	.7262	34.534
20.	1378.0	-1986.5	-378.87	-.164	7.9725	5.0030	2.2439	.7257	34.472
21.	1160.3	-1585.7	-295.37	-27.013	9.1233	5.5820	2.6794	.8618	32.384
22.	1030.8	-816.9	-157.61	-25.365	9.5238	5.6152	2.9384	.9701	28.940
23.	976.7	-245.3	-53.94	-15.449	9.4659	5.3954	3.0466	1.0239	26.348
24.	967.4	36.1	.27	-6.461	9.2658	5.1670	3.0652	1.0337	24.993
25.	976.8	114.0	17.94	-1.053	9.0971	5.0269	3.0464	1.0238	24.551
26.	988.9	95.5	16.81	1.140	9.0046	4.9712	3.0222	1.0112	24.580
27.	997.2	52.4	9.92	1.424	8.9727	4.9643	3.0056	1.0028	24.752
28.	1001.0	17.9	3.79	.965	8.9728	4.9759	2.9979	.9990	24.905
29.	1001.9	-.4	.29	.439	8.9834	4.9890	2.9962	.9981	24.992
30.	1001.4	-6.3	-.97	.096	8.9933	4.9976	2.9971	.9986	25.024

FIGURE 9B. TEST RUN(H=+$2000,T=10 DAYS;H=-$2000,T=20 DAYS)

SYSTEM ACQUISITION MODEL 5/21/77

COPIES=C,NDAYS=N,EPROC=$,PROBUD=*

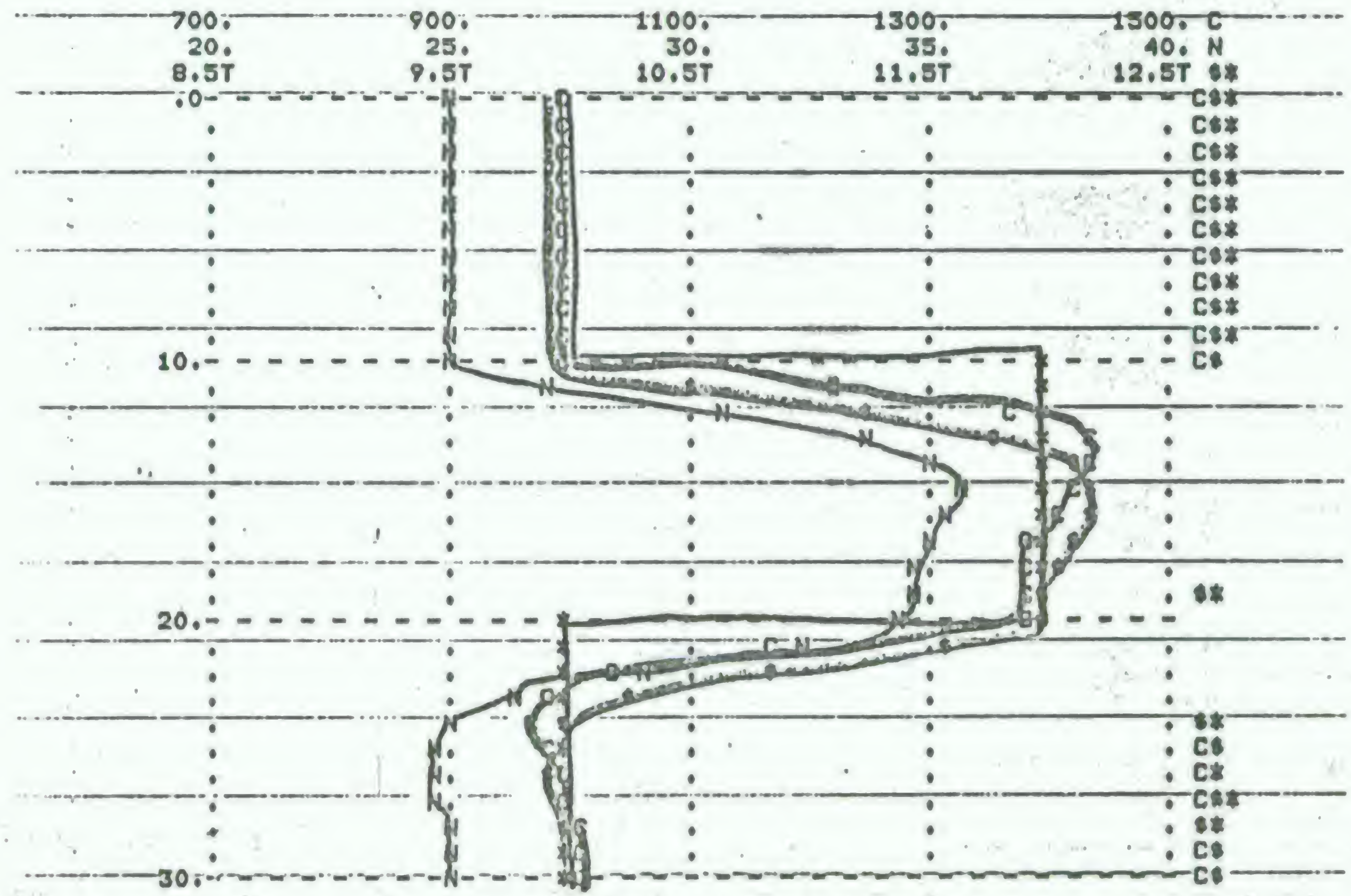


Figure 9-C SYSTEM ACQUISITION MODEL 5/21/77

PERFG=G,SPERFA=A

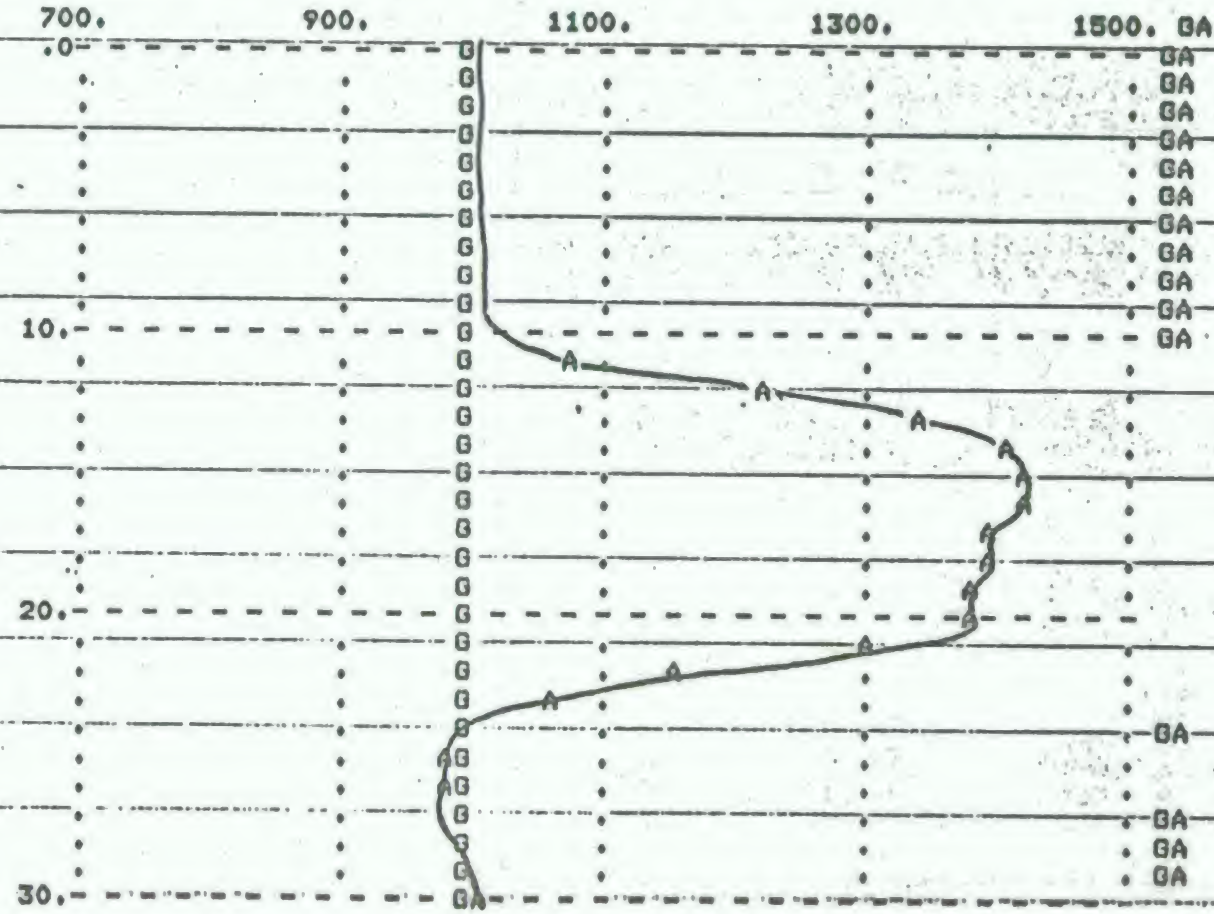


Figure 10-A TEST RUN(DT=10 Days, dt=.03125 days)

SYSTEM ACQUISITION MODEL 5/21/77 BASIC RUN

TIME	COPIES	BDISC	SPERFD	HDISC	MCPC	LABCPC	MATCPC	INCPC	NDAYS
E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00	E+00
.0	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
1.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
2.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
3.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
4.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
5.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
6.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
7.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
8.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
9.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
10.	1000.0	-1000.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
11.	905.5	-706.2	36.27	-11.649	9.615	5.3216	3.1890	1.1044	24.093
12.	852.0	-333.6	94.90	-10.622	9.781	5.3117	3.2960	1.1737	22.627
13.	831.4	-86.6	137.58	-6.207	9.727	5.1867	3.3372	1.2028	21.560
14.	829.0	23.9	158.87	-2.436	9.622	5.0735	3.3421	1.2063	21.028
15.	833.2	48.7	165.24	-.312	9.543	5.0094	3.3336	1.2002	20.869
16.	837.9	37.1	164.48	.471	9.504	4.9859	3.3243	1.1935	20.888
17.	840.8	18.9	161.81	.529	9.492	4.9843	3.3183	1.1893	20.955
18.	842.1	5.8	159.60	.339	9.493	4.9899	3.3158	1.1875	21.010
19.	842.3	-.5	158.40	.146	9.498	4.9957	3.3154	1.1872	21.040
20.	842.1	-2.3	158.00	.030	9.502	4.9991	3.3157	1.1874	21.050
21.	841.9	-1.9	158.00	-.017	9.504	5.0005	3.3162	1.1878	21.050
22.	841.8	-1.0	158.12	-.024	9.505	5.0007	3.3165	1.1880	21.047
23.	841.7	-.3	158.23	-.016	9.505	5.0005	3.3166	1.1881	21.044
24.	841.7	.0	158.30	-.007	9.505	5.0002	3.3167	1.1881	21.042
25.	841.7	-1999.9	158.33	-.001	9.505	5.0000	3.3167	1.1881	21.042
26.	673.5	-1340.7	223.92	-20.512	10.899	5.7614	3.6530	1.4848	19.402
27.	586.0	-619.8	324.66	-17.870	11.297	5.7624	3.8280	1.7065	16.883
28.	552.4	-172.2	395.91	-10.337	11.173	5.4678	3.8952	1.8103	15.102
29.	546.9	22.6	431.79	-4.259	10.929	5.1947	3.9062	1.8284	14.205
30.	551.8	69.0	443.82	-.871	10.748	5.0394	3.8963	1.8122	13.905

Figure 10-B TEST RUN (DT= 10 Days, dt= .03125 days)

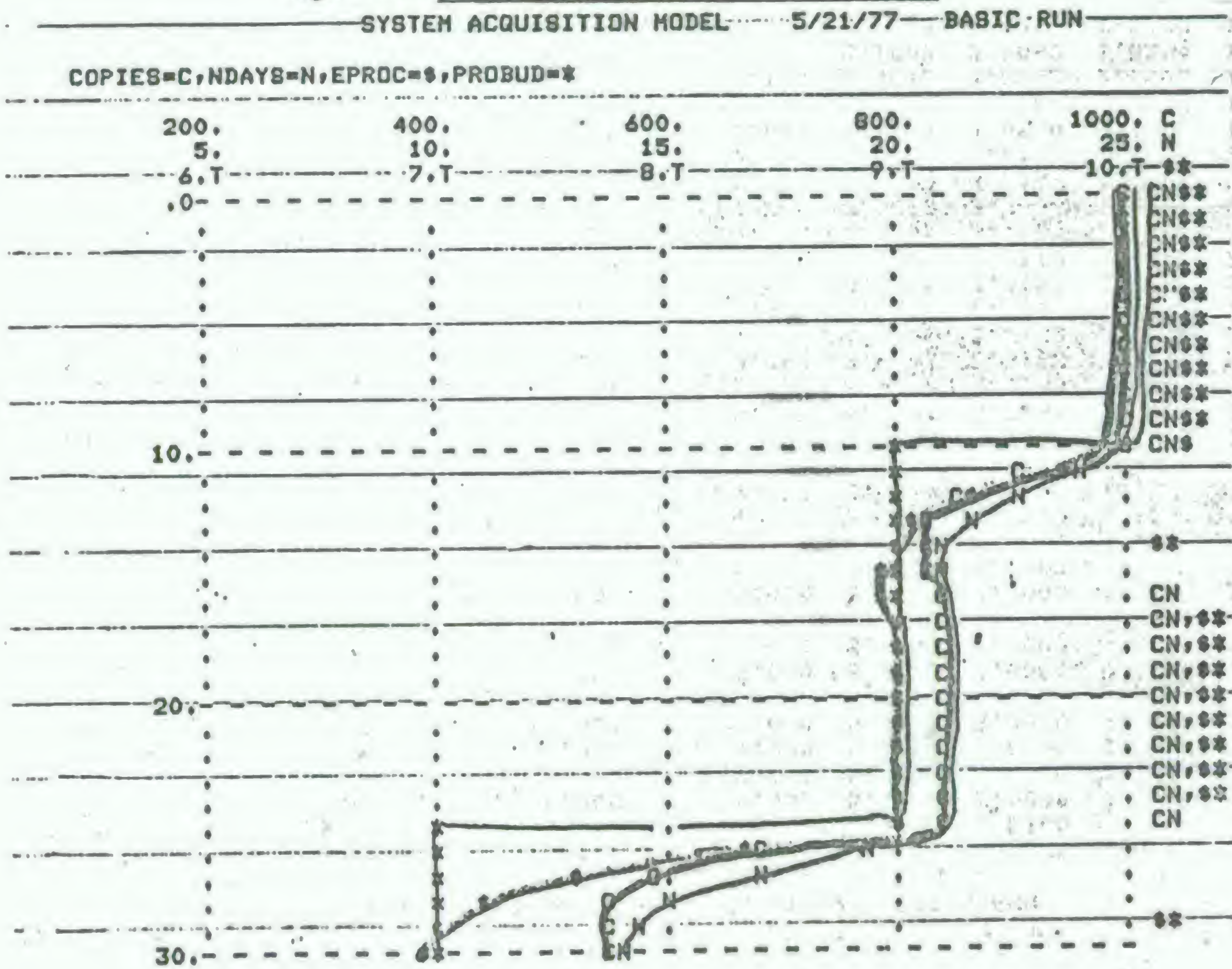
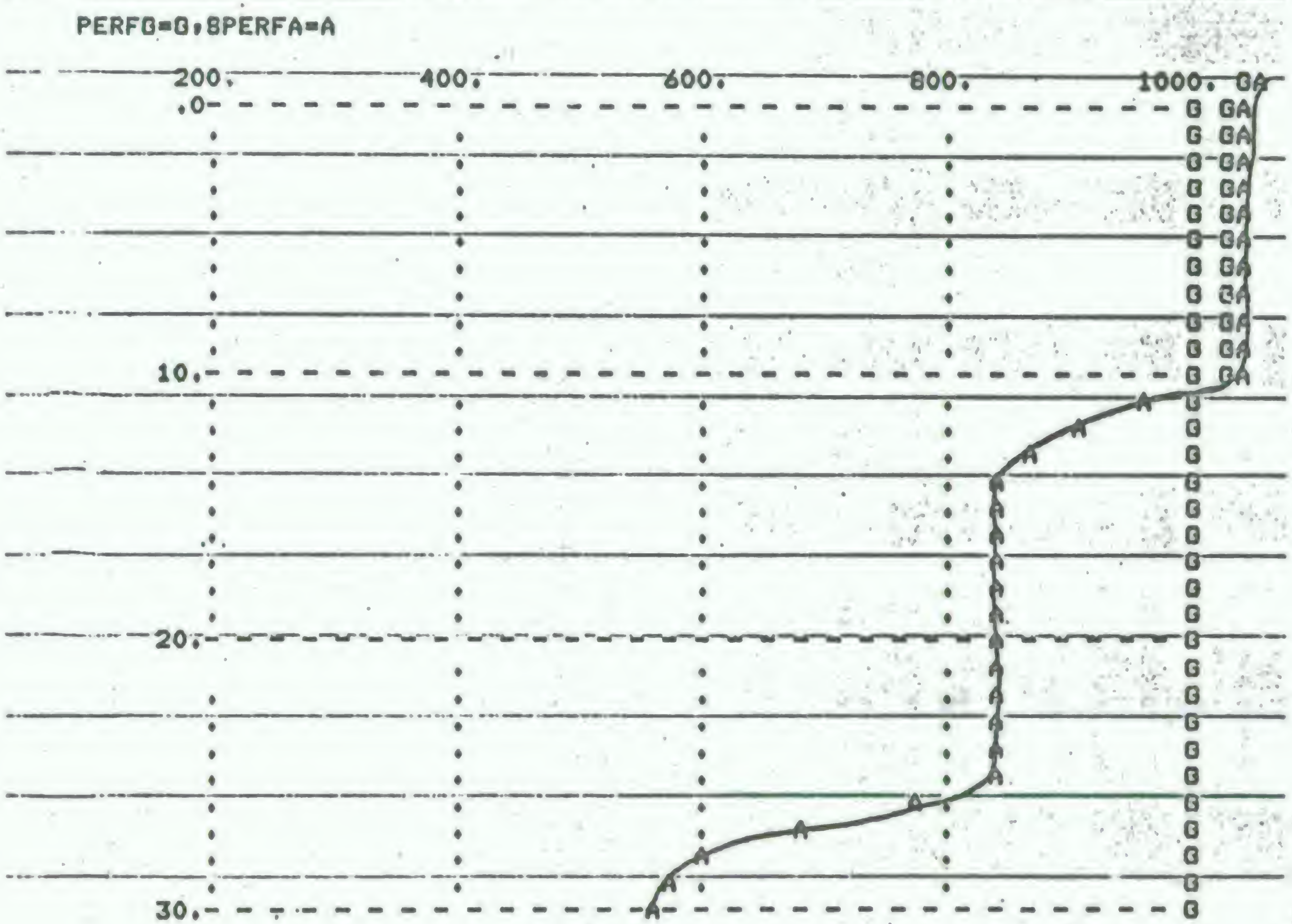


Figure 10-C TEST RUN (DT = 10 Days, dt=.03125 days)
SYSTEM ACQUISITION MODEL 5/21/77 BASIC RUN



3) STHPWD (number of Straight Time Hours Per Worker/Day)

4) TINC (Total Indirect Cost of Manufacturer)

5) RDT&E (RDT&E Costs)

6) STHR (Straight Time Hourly Rate)

7) AMPCN (Amount of Material Per Copy Normal)

8) GOAL (System Performance Goals)

9) COMM (Cost of Material Multiplier)

While all of the above nine variables can be varied and/or fixed, some combinations of fixing 2, 3 or 4 of the prime variables (days, performance/copy, budget and number of copies) may not be possible. If data provided for input is not correct, the model will indicate whether that data is critical and whether it must be accurately determined. At the same time, the model will demonstrate which data need only be reasonably accurate - perhaps could even be only loosely determined or estimated - since the four prime variables may be shown not to be sensitive to large variations in those data. A very useful capability may be the opportunity to request proposals from the contractors and then to verify the validity of their responses. Should a contractor state that requested schedules, budgets, etc., cannot be met, the model provides a check for what may be an aggregation problem rather than an impossible demand.

To test the above, a very simple analysis, not unrealistic in these days of climbing wages, was made. Wages were increased 10% across the board. As would be expected, the labor hours per copy increased ($9.00 up to $9.73), number of copies to be built with a fixed program budget dropped (1000 copies down to 924.8), and system performance discrepancy changed (from 0 to 75.186). This print-out is shown as Figure 11.[7]

Applications to Weapon Systems

The next comment from a persistent astute questioner might be:

> "Alright, I understand generally what you've been describing. But it seems to me that paper weights are a far cry from F-15's, Advanced Attack Helicopters and Aegis missiles. Can that model be used with production items incorporating thousands of moving parts, millions of 'chips,' and exotic alloys?"

---

[7] Three additional results obtained by varying inputs are included as Appendices C, D, and E.

	H	H1	H3	T3
PRESENT	0.	0.	2.500	10.00
ORIGINAL	-1000.	-2000.	0.	0.

Figure 11A TEST RUN

SYSTEM ACQUISITION MODEL 5/21/77

TIME E+00	COPIES E+00	BDISC E+00	SPERFD E+00	HDISC E+00	MCPC E+00	LABCPC E+00	MATCPC E+00	INCPC E+00	NDAYS E+00
.0	1000.0	.00	.000	.0000	9.0000	5.0000	3.0000	1.0000	25.000
1.	1000.0	.00	.000	.0000	9.0000	5.0000	3.0000	1.0000	25.000
2.	1000.0	.00	.000	.0000	9.0000	5.0000	3.0000	1.0000	25.000
3.	1000.0	.00	.000	.0000	9.0000	5.0000	3.0000	1.0000	25.000
4.	1000.0	.00	.000	.0000	9.0000	5.0000	3.0000	1.0000	25.000
5.	1000.0	.00	.000	.0000	9.0000	5.0000	3.0000	1.0000	25.000
6.	1000.0	.00	.000	.0000	9.0000	5.0000	3.0000	1.0000	25.000
7.	1000.0	.00	.000	.0000	9.0000	5.0000	3.0000	1.0000	25.000
8.	1000.0	.00	.000	.0000	9.0000	5.0000	3.0000	1.0000	25.000
9.	1000.0	.00	.000	.0000	9.0000	5.0000	3.0000	1.0000	25.000
10.	1000.0	-500.00	.000	.0000	9.5000	5.5000	3.0000	1.0000	25.000
11.	954.3	-354.12	17.450	-5.6499	9.8021	5.6628	3.0914	1.0479	24.564
12.	928.0	-164.27	46.052	-5.1963	9.8757	5.6540	3.1441	1.0776	23.849
13.	918.2	-37.16	66.844	-2.9882	9.8421	5.5895	3.1636	1.0891	23.329
14.	917.7	18.66	76.867	-1.0875	9.7869	5.5326	3.1646	1.0897	23.078
15.	920.4	29.16	79.423	-.0385	9.7469	5.5011	3.1592	1.0865	23.014
16.	923.0	20.86	78.545	.3163	9.7279	5.4906	3.1539	1.0834	23.036
17.	924.6	9.82	76.911	.3048	9.7233	5.4909	3.1508	1.0815	23.077
18.	925.2	2.33	75.689	.1795	9.7251	5.4947	3.1496	1.0808	23.108
19.	925.2	1.01	75.092	.0677	9.7283	5.4980	3.1495	1.0808	23.123
20.	925.1	-1.67	74.936	.0054	9.7306	5.4998	3.1498	1.0810	23.126
21.	924.9	-1.20	74.984	-.0164	9.7318	5.5005	3.1501	1.0812	23.125
22.	924.8	-.55	75.080	-.0157	9.7321	5.5005	3.1503	1.0813	23.123
23.	924.8	-.12	75.153	-.0089	9.7320	5.5003	3.1504	1.0813	23.121
24.	924.8	.09	75.188	-.0026	9.7318	5.5001	3.1504	1.0813	23.120
25.	924.8	.12	75.199	.0007	9.7317	5.5000	3.1504	1.0813	23.120
26.	924.8	.11	75.198	.0022	9.7316	5.4999	3.1504	1.0813	23.120
27.	924.8	.10	75.190	.0038	9.7315	5.4999	3.1504	1.0813	23.120
28.	924.8	.07	75.186	.0038	9.7315	5.4999	3.1504	1.0813	23.120
29.	924.8	. .7	75.186	.0038	9.7315	5.4999	3.1504	1.0813	23.120
30.	924.8	.07	75.186	.0038	9.7315	5.4999	3.1504	1.0813	23.120

Figure 11-B TEST-RUN

SYSTEM ACQUISITION MODEL 5/21/77

COPIES=C,NDAYS=N,EPROC=$,PROBUD=*

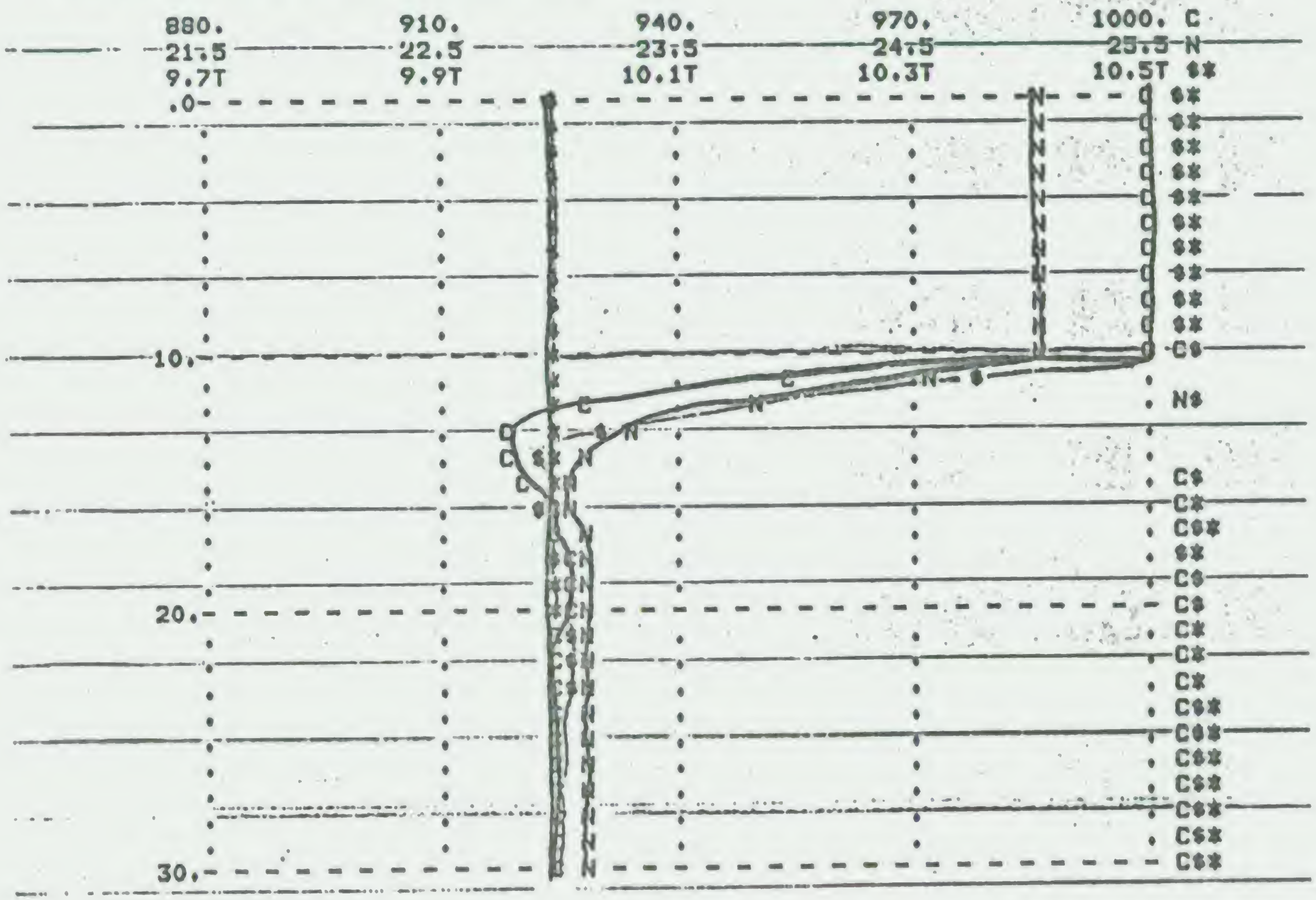
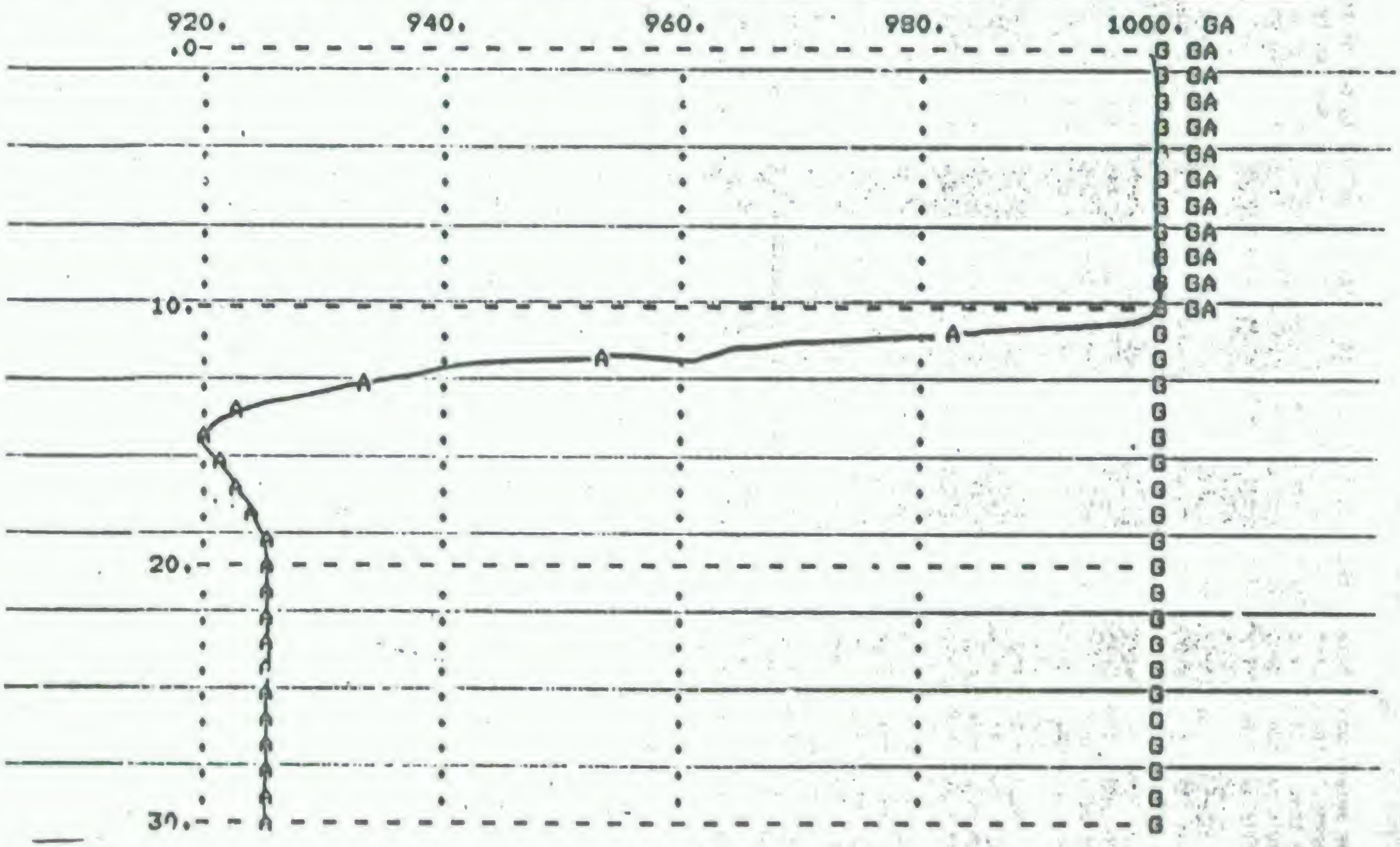


Figure 11-C TEST RUN

SYSTEM ACQUISITION MODEL 5/21/77

PERFG=G,SPERFA=A



The answer would have to be, "No, that model could not be applied to one of today's sophisticated electronics-loaded systems. But it can be expanded, section by section, so that in time - and with the expenditure of a relatively small amount of dollars - it would provide a reasonably realistic representation, sufficiently accurate and reliable to provide useful information to harried decision-makers."

Let's study the performance section (Figure 6) of the model, for example, and ask what changes would be required to start the transition from modeling the paperweight buy to modeling the F-15 acquisition process. First, the system performance goal (GOAL) must be changed from the simple, one-parameter requirement that the program's production items weigh a total of 1000 pounds (each paperweight weighs one pound). Instead, the system goal now might be to destroy in the air U percent of X attacking enemy bombers by firing a total of Y missiles from a number of F-15's.

Suppose the program budget (PROBUD) managers are alerted to the likelihood of a major cut; as noted earlier in the paper, that actually happened to the F-15 (and others) earlier this year. The proposed decreased budget amount is picked up in the model as a budget discrepancy (BDISC) between PROBUD and EPROC; that result feeds into the copies change rate (COPCR) decreasing the number of F-15's which can be purchased. This section of the model now goes through an iterative process, adjusting the number of copies that can be produced as various material quantity discounts are taken into account, overtime hours (if previously scheduled) are reduced and so on. When the number of copies being procured stabilizes, that figure is fed to the actual system performance change rate (SPERFC). Almost at the same moment, the performance per copy (PERFPC) information is inputted to the actual system performance change rate (SPERFC), and the product (SPERFA or actual system performance) of the two - copies and performance per copy - is compared to the system performance goal (GOAL). As expected, fewer copies times the same performance per copy produces a discrepancy in system performance versus the goal.

At this point the decision makers can see a computer generated break-out of the following:

COPIES	-	Number of Copies Being Procured (with reduced budget)
SPERFD	-	System Performance Discrepancy (between goal and now estimated)
NDAYS	-	Number of Days Scheduled (to produce the reduced quantity)
INCPC	-	Indirect Costs Per Copy
MATCPC	-	Material Costs Per Copy (change due to lower quantities being acquired)
LABCPC	-	Labor Costs Per Copy
MCPC	-	Manufacturers Cost Per Copy

If the lowered capability to destroy percent of enemy bombers is unacceptable, the program managers might propose increasing the number of missiles to be carried per aircraft. Therefore, performance per copy (PERFPC) increases as does labor hours per copy (LABH). The result of these two changes is an increase in actual system performance (due to higher performance/copy times the reduced quantity of aircraft) and more days therefore more labor costs and eventually a budget discrepancy. Now the print-out would show that to increase the actual system performance, by the added

missiles, would cost a specified extra number of dollars. The ultimate decision-maker then has a choice between the initial reduced quantity and reduced system performance and reduced budget versus the same reduced quantity, less of a reduction in system performance and a budgetary position between the initial and first reduction.

Of course, the model would allow consideration of a program stretch-out, without reducing total quantity to be produced. Here, however, the indirect costs would change and that result would have to be evaluated.

. Other sorts of questions that might be asked of the simulation, so to speak, could include adding performance per copy parameters such as take-off weight, turn radius, time to altitude, maximum altitude, and so forth. Each of these can be tied to a discrepancy indicator as well as performance change rate values. It would, therefore, be possible to assess the impact of increased weight on each of these and to also design in trade-off decisions.

Other methods for handling system performance analysis might include selecting five or six major indicators of performance and assigning percentages to the current estimate for each as compared to the goal. Again, discrepancies could be calculated for each or system performance could be a number based on the product of copies to be procured times the product of the six major indicators averaged. These methods mights be considered similar to that used with the C-5A when initial program goals were broached in terms of each C-5A being equivalent to a certain number of C-141's. The question of where the current developmental model stood vis-a-vis the goal, was answered by saying, "This model would be the equivalent of 2.5 C-141's."

Conclusion

As we admitted earlier - and it is worth repeating again here - our model is very primitive in its present form: it was designed to be. We do not recommend its use, and there are perhaps other methodologies that can deliver the same results. What we do suggest is that this approach leads to a simulation model that is easy to construct and use by an SPO who is interested in managing a system, not becoming a computer or modeling expert. This primitive model can easily be expanded as necessary to reflect the real system within which the SPO finds himself making decisions and expanded in terms of his own managerese, not computerese. Anything he considers important, if he can describe it in ordinary English, can be included. By developing a simple simulation model and showing how it proceeds through the calculations necessary in a few example changes, we hope we have interested you in a way of tackling much more complicated systems. We hope we have interested you in a new - and potentially helpful - management tool for understanding and managing cost, performance and schedule changes interactions in the Weapon System Acquisition planning and control process.

Potentially there might be an even greater benefit through using the DYNAMO simulation as a research tool to investigate poorly understood phases of the weapons acquisition process. So, while we'd claim with a nigh degree of confidence that the model can be modified to furnish a realistic learning tool, we do not claim for a second that total familiarity in its use and workings will eliminate cost growth, performance shortfalls and schedule slips. We do insist, however, that use of the expanded model would permit decision-makers to assess in advance the results of variable options; it might also avoid some of the on-and-off-again decisions that are sometimes found in the acquisition of major weapon systems.

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00010probud  program budget
00020bdisc  budget discrepancy
00030eproc  estimated program costs
00040rdte  research, development, test and evaluation costs
00050mcpc  manufacturers costs per copy
00060incpc  indirect costs per copy
00070tinc  total indirect costs of manufacturer
00080copies  number of copies being procured
00090labcpc  labor costs per copy
00100copcr  copies change rate
00110ampcn  amount of material per copy normal
00120qomp  quantity of material purchased
00130comm  cost of material multiplier
00140compu  cost of material per copy
00150comt  total cost of material
00160matcpc  material cost per copy
00170labtc  total cost of labor
00180tstrtc  total straight time costs
00190sthr  straight time hourly wage rate
00200tsthrs  total number of straight time hours
00210sthpwd  number of hours per worker per day
00220ndays  number of days scheduled
00230ndcr  number of days for schedule change
00240hdisc  number of hours discrepancy
00250tsthrr  total straight time hours required
00260lhpc  labor hours per copy
00270labh  labor hours table function
00280perfpc  performance per copy
00290perfcc  performance per copy change rate
00300sperfa  actual system performance
00310sperfc  actual system performance change rate
00320sperfd  system performance discrepancy
00330goal  system performance goal
```

APPENDIX B-1

```
00010 * WEAPON SYSTEM ACQUISITION MODEL
00020 L     PROBUD.K=PROBUD.J+(DT)(BUDCR.JK)  PROGRAM BUDGET
00030 N     PROBUD=PROBUDI
00040 C     PROBUDI=10000 DOLLARS
00050 R     BUDCR.KL=STEP(H,T)  BUDGET CHANGE RATE
00060 C     H=0
00070 C     T=0
00080 NOTE
00090 NOTE  NUMBER OF COPIES SECTOR
00100 NOTE
00110 L     COPIES.K=COPIES.J+(DT)(COPCR.JK)  NUMBER OF COPIES PLANNED
00120 N     COPIES=COPIESI
00130 C     COPIESI=1000 COPIES AT 10 DOLLARS PER COPY
00140 R     COPCR.KL=COPCA.K  CHANGE RATE IN COPIES
00150 A     COPCA.K=BDISC.K/MCPC.K   COPIES CHANGE AUX
00160 A     BDISC.K=PROBUD.K-EPROC.K  BUDGET DISCREPANCY
00170 A     MCPC.K=MATCPC.K+LABCPC.K+INCPC.K   MANUFACTURERS COST PER COPY
00180 A     EPROC.K=MCPC.K*COPIES.K+RDTE
00190 C     RDTE=1000   RDTE COTSTS
00200 NOTE
00210 NOTE   INDIRECT COSTS SECTOR
00220 NOTE
00230 A     INCPC.K=TINC/COPIES.K  INDIRECT COST PER COPY
00240 C     TINC=1000 DOLLARS
00250 NOTE
00260 NOTE   MATERIAL COSTS SECTOR
00270 NOTE
00280 A     MATCPC.K=COMT.K/COPIES.K  MATERIAL COSTS PER COPY
00290 A     COMT.K=QOMP.K*COMPU.K  COST OF MATERIAL TOTAL
00300 A     QOMP.K=AMPCN*COPIES.K  QUANTITY OF MATERIAL PURCHASED.
00310 C     AMPCN=1 POUND AMOUNT OF MATERIAL PURCHASED PER COPY NORMAL
00320 A     COMPU.K=TABHL(COMM,QOMP.K,500,1500,500) COST OF MATERIAL PJURCHASED
00330 T     COMM=4/3/2
00340 NOTE
00350 NOTE  LABOR COSTS SECTOR
00360 NOTE
```

```
00370 A     LABCPC.K=LABTC.K/COPIES.K  LABOR COSTS PER COPY
00380 A     LABTC.K=TSTRTC.K  TOTAL LABOR COSTS
00390 A     TSTRTC.K=STHR*TSTHRS.K  TOTAL STRATING-TIME COTST
00400 C     STHR=25 DOLLARS PER HOUR  STRAIGHT HOURLY RATE
00410 A     TSTHRS.K=NDAYS.K*STHPWD  TOTAL STRAIGHT TIME HOURS
00420 C     STHPWD=8 HOURS PER WORKER PER DAY
00430 NOTE
00440 NOTE PROGRAM SCHEDULESECTOR
00450 NOTE
00460 L     NDAYS.K=NDAYS.J+(DT)(NDCR.JK) N DAYS TO PRODUCE
00470 N     NDAYS=NDAYSI
00480 C     NDAYSI=25 DAYS
00490 R     NDCR.KL=HDISC.K/STHPWD  N DAYS ADDED OR SUBTRACTED
00500 A     HDISC.K=TSTHRR.K-TSTHRS.K  HOUR DISC
00510 A     TSTHRR.K=COPIES.K*LHPC.K  HOURS PER COPY
00520 A     LHPC.K=TABHL(LABH,PERFPC.K,.5,1.5,.5)  LABOR HOURS/COPY
00530 T     LABH=.1/.2/.4
00540 A     PERFG.K=GOAL+STEP(HGHT,STM)  PERFORMANCE GOAL FOR SYSTEM
00550 C     HGHT=0
00560 C     STM=0
00570 C     GOAL=1000 POUNDS FOR SYSTEM WEIGHT
00580 A     SPERFD.K=PERFG.K-SPERFA.K  SYSTEM PERFORMANCE DISC
00590 L     SPERFA.K=SPERFA.J+(DT)(SPERFC.JK-SPERFA.J)
00600 N     SPERFA=SPERFAI
00610 C     SPERFAI=1000
00620 R     SPERFC.KL=PERFPC.K*COPIES.K  SYSTEM PERFORMANCE
00630 L     PERFPC.K=PERFPC.J+(DT)(PERFCC.JK-PERFPC.J)  PERFORMANCE PER COPY
00640 N     PERFPC=PERFPCI
00650 C     PERFPCI=1 POUND PER COPY
00660 R     PERFCC.KL=QOMP.K/COPIES.K  PERFORMANCE PER COPY
00670 C     DT=1 DAY
00680 C     PRTPER=1
00690 C     PLTPER=1
00700 PRINT COPIES,DDISC,SPERFD,HDISC,MCPC;LABCPC,MATCPC,INCPC,NDAYS
00710 PLOT  COPIES=C/NDAYS=D/MCPC=$
00720 C     LENGTH=30 DAYS
00730 RUN BASIC RUN
END OF DATA
```

	COMM		
PRESENT	3.000	3.000	3.000
ORIGINAL	4.000	3.000	2.000

SYSTEM ACQUISITION MODEL 5/21/77 NO DISCOUNT ON MATERIAL

TIME E+00	COPIES E+00	BDISC E+00	SPERFD E+00	HDISC E+00	MCPC E+00	LABCPC E+00	MATCPC E+00	INCPC E+00	NDAYS E+00
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5.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
6.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
7.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
8.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
9.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
10.	1000.0	-1000.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
11.	913.1	-568.5	34.17	-10.537	9.384	5.2885	3.0000	1.0951	24.146
12.	873.3	-198.2	84.31	-8.480	9.388	5.2427	3.0000	1.1451	22.892
13.	863.4	-10.0	116.02	-4.123	9.278	5.1194	3.0000	1.1583	22.099
14.	866.0	44.7	128.53	-1.093	9.186	5.0316	3.0000	1.1547	21.787
15.	870.8	38.7	130.23	.215	9.142	4.9938	3.0000	1.1483	21.744
16.	874.0	19.3	128.28	.465	9.131	4.9867	3.0000	1.1441	21.793
17.	875.3	5.3	126.25	.318	9.133	4.9909	3.0000	1.1424	21.843
18.	875.5	-.8	125.14	.134	9.138	4.9962	3.0000	1.1422	21.871
19.	875.3	-2.1	124.78	.024	9.142	4.9993	3.0000	1.1424	21.880
20.	875.1	-1.4	124.79	-.015	9.143	5.0004	3.0000	1.1427	21.880
21.	875.0	-.6	124.89	-.018	9.143	5.0005	3.0000	1.1428	21.878
22.	875.0	-.1	124.97	-.010	9.143	5.0003	3.0000	1.1429	21.876
23.	875.0	.1	125.00	-.002	9.143	5.0001	3.0000	1.1429	21.875
24.	875.0	.1	125.01	.001	9.143	5.0000	3.0000	1.1429	21.875
25.	875.0	-1999.9	125.01	.002	9.143	4.9999	3.0000	1.1429	21.875
26.	708.0	-1169.0	191.00	-20.201	10.126	5.7133	3.0000	1.4124	20.225
27.	630.1	-453.2	287.42	-16.498	10.242	5.6546	3.0000	1.5871	17.814
28.	606.5	-66.7	350.57	-8.585	10.003	5.3539	3.0000	1.6488	16.236
29.	607.9	67.0	378.15	-2.787	9.760	5.1146	3.0000	1.6450	15.546
30.	615.8	73.7	384.22	.003	9.624	4.9999	3.0000	1.6239	15.394

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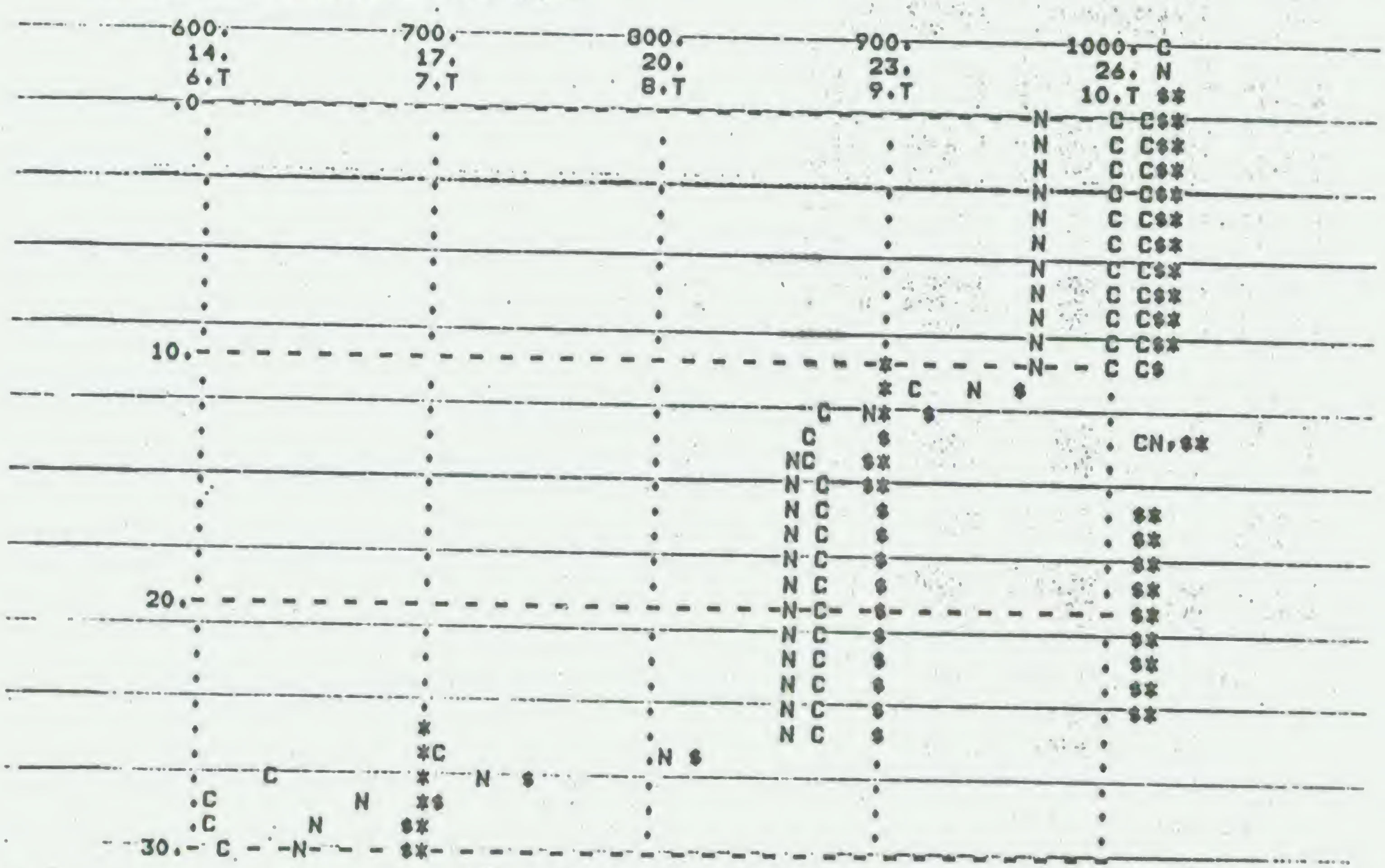

APPENDIX C-3

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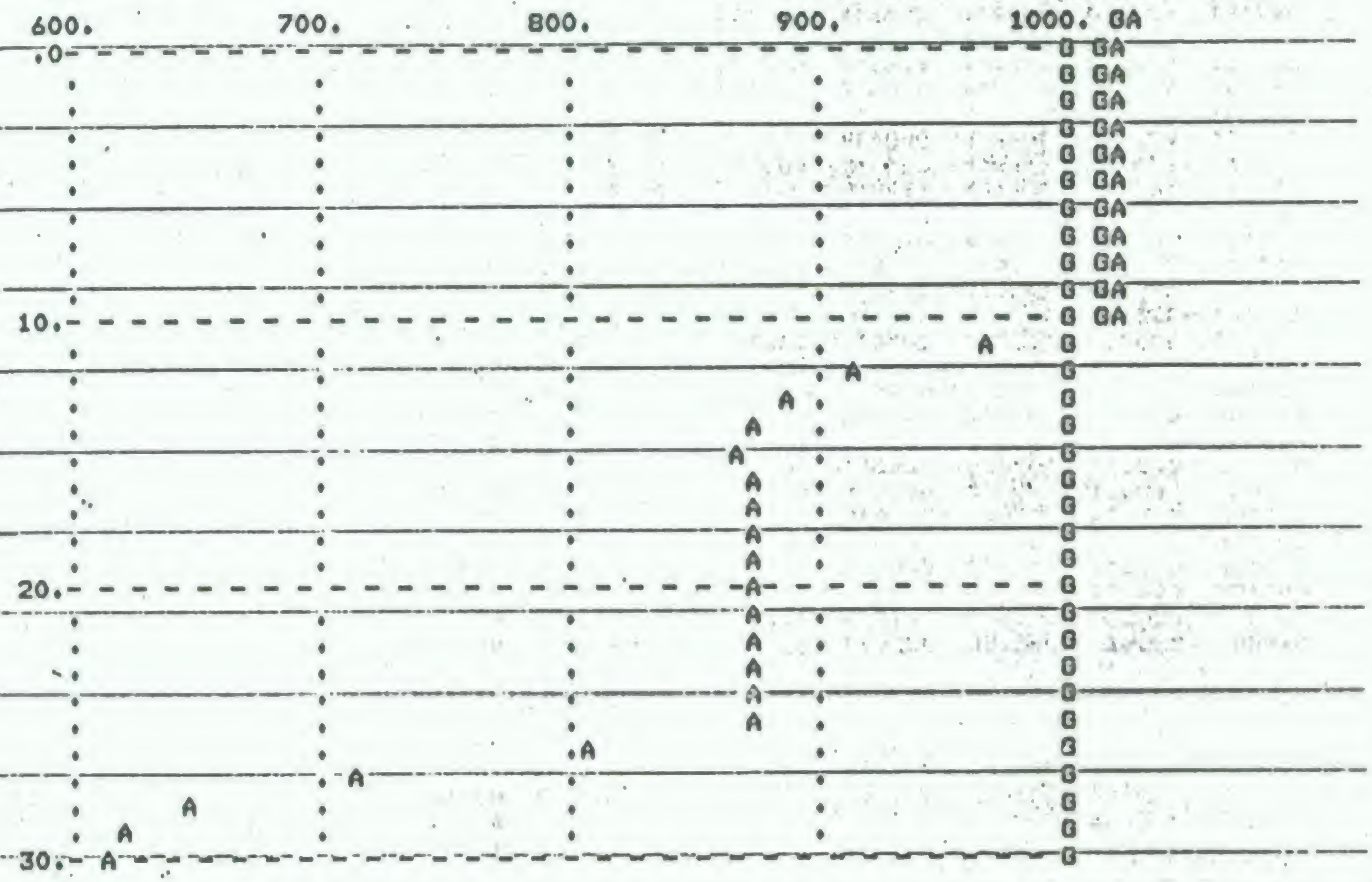

	COMM		
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ORIGINAL	4.000	3.000	2.000

SYSTEM ACQUISITION MODEL 5/21/77 LOW COPIES-HIGH-COMPU

TIME E+00	COPIES E+00	BDISC E+00	SPERFD E+00	HDISC E+00	MCPC E+00	LABCPC E+00	MATCPC E+00	INCPC E+00	NDAYS E+00
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1.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
2.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
3.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
4.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
5.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
6.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
7.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
8.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
9.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
10.	1000.0	-1000.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
11.	888.5	-1055.8	40.83	-14.137	10.192	5.3978	3.6691	1.1255	23.979
12.	800.7	-761.9	119.54	-15.954	10.943	5.4981	4.1959	1.2489	22.011
13.	747.5	-417.8	191.42	-12.215	11.261	5.4085	4.5150	1.3378	20.214
14.	722.1	-166.5	240.76	-7.419	11.309	5.2568	4.6671	1.3848	18.981
15.	714.1	-27.3	267.98	-3.581	11.241	5.1254	4.7154	1.4004	18.300
16.	714.6	30.0	279.50	-1.177	11.153	5.0412	4.7123	1.3994	18.012
17.	718.0	41.5	282.07	.023	11.084	4.9992	4.6918	1.3927	17.948
18.	721.5	33.4	280.71	.445	11.042	4.9846	4.6709	1.3860	17.982
19.	724.0	20.8	278.34	.465	11.021	4.9839	4.6561	1.3812	18.041
20.	725.4	10.2	276.31	.337	11.015	4.9884	4.6478	1.3786	18.092
21.	726.0	3.4	274.99	.193	11.015	4.9934	4.6442	1.3775	18.125
22.	726.1	.0	274.31	.085	11.018	4.9971	4.6434	1.3772	18.142
23.	726.0	-1.2	274.07	.022	11.020	4.9992	4.6438	1.3773	18.148
24.	725.9	-1.3	274.04	-.006	11.022	5.0002	4.6445	1.3776	18.149
25.	725.8	-2000.9	274.11	-.014	11.023	5.0005	4.6451	1.3778	18.147
26.	574.4	-1527.4	332.50	-18.618	13.105	5.8103	5.5536	1.7409	16.687
27.	487.6	-793.5	426.43	-17.192	13.932	5.8815	6.0000	2.0508	14.339
28.	452.5	-234.5	496.09	-10.284	13.778	5.5682	6.0000	2.2100	12.598
29.	444.9	-6.9	532.51	-4.519	13.502	5.2539	6.0000	2.2477	11.687
30.	447.1	49.3	546.35	-1.315	13.310	5.0735	6.0000	2.2367	11.341

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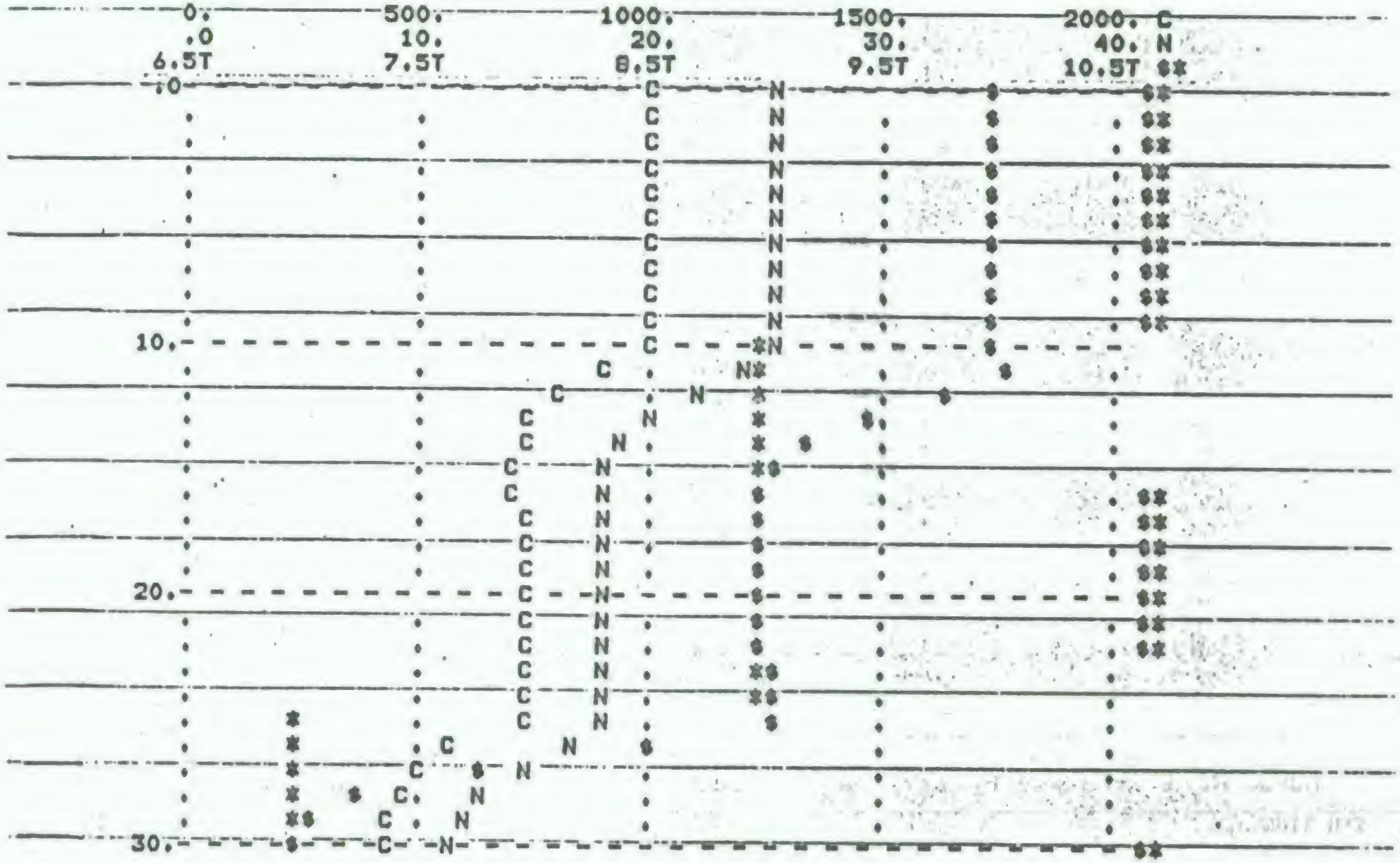

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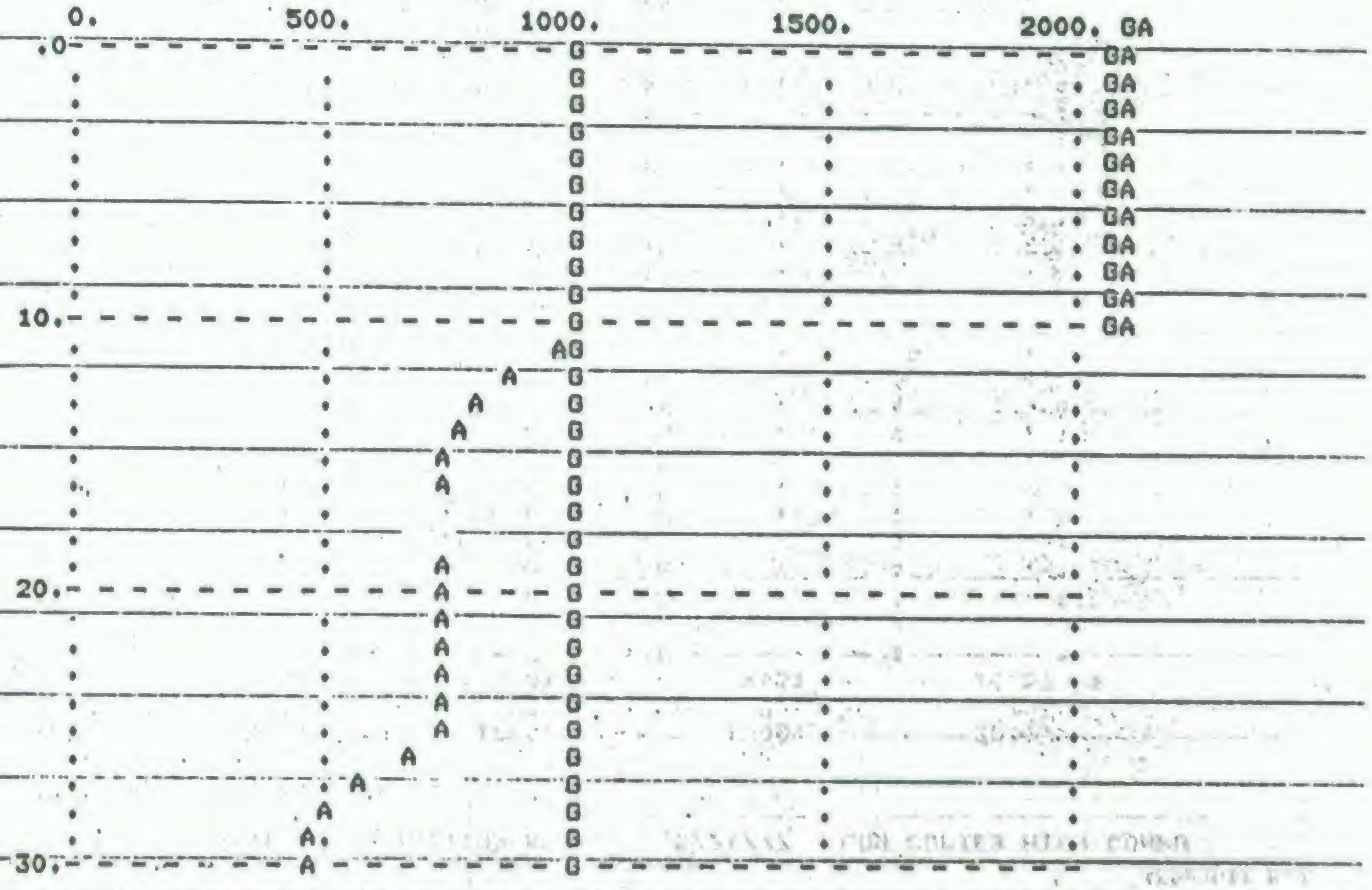

	H3	T3	T1
PRESENT	2.500	20.00	35.00
ORIGINAL	0.	0.	25.00

APPENDIX B-1

SYSTEM ACQUISITION MODEL 5/21/77

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1.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
2.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
3.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
4.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
5.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
6.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
7.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
8.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
9.	1000.0	.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
10.	1000.0	-1000.0	.00	.000	9.000	5.0000	3.0000	1.0000	25.000
11.	905.5	-706.2	36.27	-11.649	9.615	5.3216	3.1890	1.1044	24.093
12.	852.0	-333.6	94.90	-10.622	9.781	5.3117	3.2960	1.1737	22.627
13.	831.4	-86.6	137.58	-6.207	9.727	5.1867	3.3372	1.2028	21.560
14.	829.0	23.9	158.87	-2.436	9.622	5.0735	3.3421	1.2063	21.028
15.	833.2	48.7	165.24	-.312	9.543	5.0094	3.3336	1.2002	20.869
16.	837.9	37.1	164.48	.471	9.504	4.9859	3.3243	1.1935	20.888
17.	840.8	18.9	161.81	.529	9.492	4.9843	3.3183	1.1893	20.955
18.	842.1	5.8	159.60	.339	9.493	4.9899	3.3158	1.1875	21.010
19.	842.3	-.5	158.40	.146	9.498	4.9957	3.3154	1.1872	21.040
20.	842.1	-423.3	158.00	.030	10.002	5.4990	3.3157	1.1874	21.050
21.	806.1	-286.4	171.74	-4.426	10.279	5.6510	3.3877	1.2405	20.706
22.	786.1	-128.0	193.93	-3.989	10.339	5.6395	3.4278	1.2721	20.152
23.	779.0	-27.6	209.76	-2.252	10.305	5.5795	3.4421	1.2837	19.756
24.	778.7	14.4	217.28	-.812	10.256	5.5287	3.4427	1.2843	19.568
25.	780.6	21.4	219.21	-.041	10.221	5.5014	3.4388	1.2811	19.520
26.	782.4	14.9	218.65	.213	10.206	5.4925	3.4352	1.2781	19.534
27.	783.5	6.9	217.55	.205	10.202	5.4928	3.4331	1.2764	19.561
28.	783.9	1.6	216.73	.120	10.204	5.4958	3.4323	1.2757	19.582
29.	783.9	[illegible]	216.33	.046	10.206	5.4984	3.4322	1.2757	19.592
30.	783.8	-1.0	216.22	.005	10.208	5.4998	3.4324	1.2758	19.594

SYSTEM ACQUISITION MODEL 5/21/77

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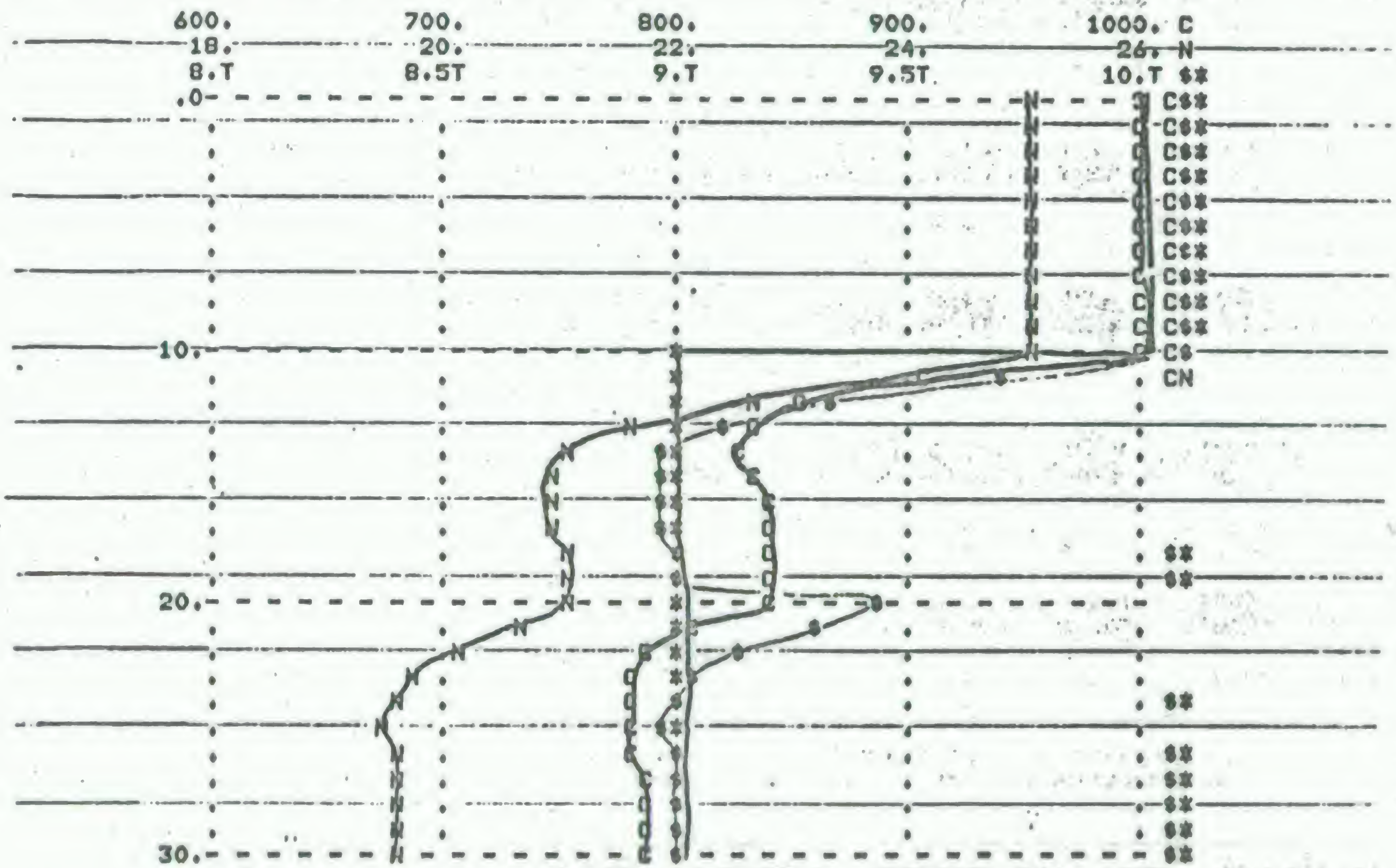

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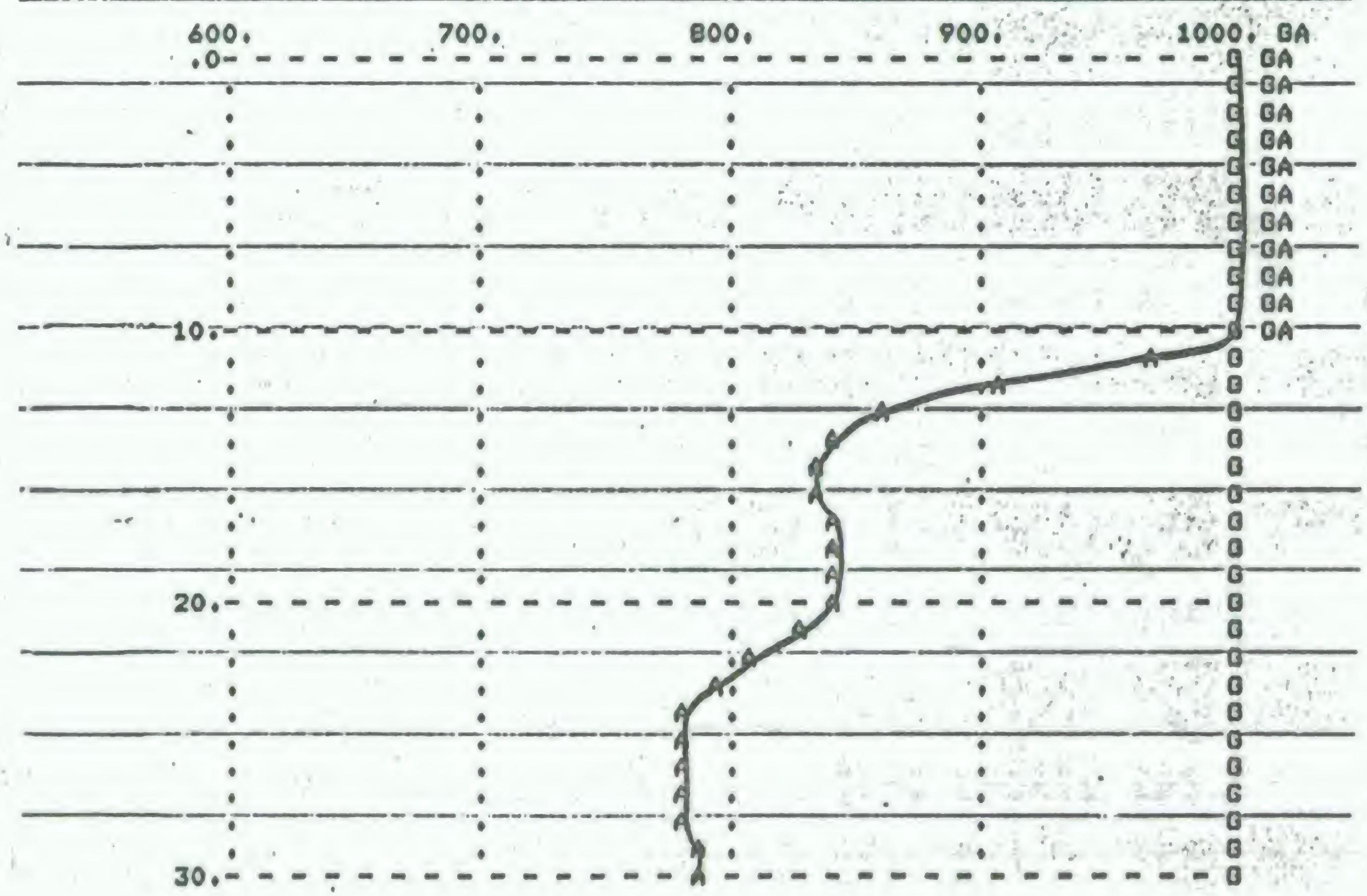

THE SOURCES OF DISRUPTION TO PROJECT COST AND DELIVERY PERFORMANCE*

E.B. Cochran, A.J. Rowe

I. INTRODUCTION

There has been much attention to the massive overruns of cost and delivery promises in U.S. military programs. The emphasis on corrective action has focused on developing better management techniques. This, however, overlooks the major contribution to overrun created by the concurrency of product development with production, in the presence of an urgent commitment to deliver operable units.

Concurrency of development and production affects production through the inevitable design delays and changes. The resulting disruption of operations is the major reason for project cost overruns (often running fifty percent or more) and schedule slippage. The general consequences of concurrency have long been recognized. But the causal mechanisms have not been fully understood, and so the possibilities of avoiding or mitigating the problem have not been exploited.

The research reported here provides an expanded understanding of the disruption process and proposes specific ways to deal with it. An important conclusion is that disruptions of both commercial and military programs are created by essentially the same causes, and so are responsive to similar preventive actions.

- Prior Research on Disruption Effects -

Early work on the S-Curve by Cochran(1) shows that major overruns in direct labor were due to time compression which resulted from inadequate time for design and production startup. This was further developed by demonstrating numerous ways in which such costs are caused by design delays and changes, production interruptions and related manpower turbulence(2). The S-Curve can also be used to estimate startup costs, which are themselves a less serious form of disruption to regular production operations. Later development of a computer model further demonstrated the effect of design delays and changes on complex steel fabrication work. Detailed diagrams for the labor disruption process then described explicitly how design uncertainty causes disruption in production runs. This work was supplemented by development of a computer model to estimate the effect of concurrency events on labor hours.

Since the late 1950's, the Rand Corporation has conducted studies to describe the inherent uncertaintly of the product development process. From early 1960 to date it has issued a number of increasingly specific reports to show that design and production concurrency accompanies large overruns, which were avoided when development work substantially preceded production. In this work, Rand developed quantitative measures of the degree of advance in state of the art (SOAA) for specific products, and demonstrated impressive correlation between that degree and the proportion of cost overrun for cases of design and production concurrency. As a result, Rand researchers recommend reducing uncertainty in advanced technology programs by return to "incremental" product development** - a procedure which has long been used by manufacturers of commercial products with stable design.

Notes:
** See the selected readings list at the end of this paper, especially items 2, 4, 8, 9, 11, 17, 19 and 21.

- Further Research -

The research reported here, conducted jointly by the University of Southern California and Cochran, integrates and extends the results described above. This work included the compiling of an extensive bibliography dealing with disruption, case studies covering both military and commercial projects and extensive analysis of the disruption process and its causes. Detailed results will be published in a book on the subject of disruption.

The case studies covered eight major projects in detail, plus briefer review of many others. Over twenty causes of disruption were identified, which were reduced to four categories useful in judging the propensity for disruption in a given case.

- Degree of technological uncertainty, based on advance in state of the art and interrelatedness.
- Delivery urgency, as reflected in the time compression of delivery schedules due to overlap of design and production phases.
- Level of resources applied.
- Amount of external control exerted, as by market requirements and environmental demands.

Assuming no outside catastrophic events occur, and that project management is reasonably sound, the amount of disruption can be viewed as a function of these four basic variables.

* * *

The remainder of this paper will describe the difficulties of concurrency in more specific terms, outline ways by which to quantify the cost effects and present important policy recommendations. Close attention also will be given to the thorny question of the role played by management competence in a disruption situation involving concurrency of design and production. The current stage of disruption theory resembles the earlier stages of queuing theory, which provided the basis for marked improvement in scheduling procedures over a number of years. Equally major improvements in the management of disruption are anticipated.

II. BASIC CONCEPTS OF DISRUPTION

1. Key Concepts

- What Is Disruption? -

"Disrupt" means to cause disorder or turmoil. In our context, the term disruption refers to the disorder and turmoil created in a program plan and in related production procedures, which naturally are aimed at minimizing costs.

Hence, "disruption cost" is the difference between the actual cost for a program on the one hand, and the cost "reasonably required" to perform the task and construct the hardware in the configuration finally delivered to the customer, on the other. We shall term this estimate the "should-cost as-built". It includes

the estimated cost of all changes incorporated in the product as if known when production was planned; it does not include penalties caused by the late incorporation of changes (retrofit, rework, lost learning, etc.).

The existence of a sizable overrun always raises the question as to the adequacy of the estimate used to determine the size of that overrun. For example, the overrun may reflect a poor assessment or errors in the estimating process, both leading to a low estimate; such a discrepancy itself could well be disruptive. We shall use an "objective" definition of disruption, with the should-cost to be a realistic estimate for the organization. This suggests using "parametric" estimating methods, which deal with fundamental characteristics of the product(3).

The importance of "product development" in this discussion leads us to state our definition, which follows one given by Glennan in 1967*:

> "Development is the obtaining of a proven capability to produce a product or process that differs significantly from anything obtained in the past ... The product is sufficiently different from previous products in that there are substantial uncertainties surrounding its technical aspects". (Emphasis supplied).

A prime purpose of development is to reduce that uncertainty to an acceptable level. The term "design" often refers to the output of an engineer's activity of "designing", presumably in the form of plans and specifications. In this sense, design is only a part of the product development cycle, which may require several re-designs. However, for simplicity here we shall refer to the entire development process as "design", in the broader sense that the design is really not complete until it is ready for production.

There are three basic causes of disruption: force majeure, concurrency of product development (or design) and production, and inadequate planning and management. Force majeure covers such catastrophic outside events as a natural disaster, civil disorder, major strike, fire, etc. Concurrency of design and production disrupts an organization by introducing the uncertainty inherent in the design process. This can have serious effects on performance when production must proceed before the design is complete, in order to meet a tight deadline. Obviously the seriousness of the disruption has something to do with the degree of overlap between the design and production processes.

Good planning and management is of great importance to a new program. The task must be well understood and thoroughly planned at the onset, adequate resources of men, materials, facilities and money must be available at the appropriate times and the program must be administered with suitable precision and detailed control over operations. It is not easy to arrive at a clearcut judgment as to management inadequacy, especially in the presence of concurrency, which can virtually preempt even the best management. For how can management understand or plan tasks in advance when the task may change materially over the course of the project? Part IV will discuss this subject further.

- - - - - - - - - - - -

Note: * Selected readings, Item 4, page 4.

- The Importance of Concurrency -

It may give concreteness to the reality of disruption if we look briefly at a few examples*:

Project	Percent Overrun	Project	Percent Overrun
Roman Aqueduct	100%	BART System	63%
Suez Canal	200	Washington Metro	80
Panama Canal (U.S.)	70	The Great Eastern	138
Indian Head atomic power plant	250	Convair B58	300
3 AEC facilities	82	Lockheed C5A	86
		Rolls Royce RB211	175

The overruns go as high as 300%, meaning that the final project costs were up to four times the original estimate**. All these programs involved concurrency—for example, any of the construction-oriented projects involve substantial work beneath the surface of the earth which inherently involves the exploration of new conditions, in addition to a high degree of technology. The sharp difference in overrun for the two aircraft cases has been shown to be related to a similar difference in the SOAA of the two projects, while the Great Eastern was a major technological advance in England in the 1850's.

The great importance of concurrency as a cause of overruns is a matter of direct experience to thousands of managers in high-technology industry. It has also been extensively documented by a series of Rand Corporation studies. For example, after some twenty years of studying complex development programs in the U.S. and abroad, a 1971 report concluded that:#

> "High system cost and cost growth appear to arise primarily from efforts to subdue difficult technology on highly compressed schedules ... (and the) acceptance of optimistic assumptions about the long-term predictability of technology and the cost of coping with it."

In summary, the Rand studies also show that cost and schedule problems are greater as the degree of SOA advance increases, sophisticated management planning and control programs and incentive contracting have small effect, and improvement through better cost estimating and monitoring of cost growth does not seem substantial. Concurrency may not even reduce development time significantly.

In short, the main problem lies in the concurrency itself, with the uncertainty that it contains and the effect of that on development and production costs in the presence of urgent time schedules. Thus, these studies recommend incremental procedures for product development. While the most exhaustive studies have involved large military programs, the operation of concurrency applies equally to commercial programs. Any industry involving advanced technology and competitive pressures for early delivery will be a prime candidate, as will be apparent when we describe the mechanisms by which concurrency produces its dismal effects.

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Notes:

* These are generally items from the selected readings; most are from publications by Rand personnel, except those on the Great Eastern, the Roman Aqueduct and the two rapid transit systems.

** In most cases the effect of inflation has been removed from these figures, as has the fact that the scope of a program is often reduced as overruns develop in order to stay within reasonable distance of the funding available.

\# Selected readings, Item 11, page 39.

2. Factors in Concurrency Disruption

Exhibit II-A displays the major factors involved in a disruption due to concurrency of design and production. There are two principal causes. First, a high degree of delivery urgency which forces product development to overlap with the planning and initiation or production. Second, a considerable degree of technological uncertainty in the development work which must be done.

Delivery urgency generally arises from marketing considerations. The demands of a particular customer, enforced by competitive conditions, exerts strong pressure on suppliers to commit to delivery dates which are inherently optimistic or based on the assumption that no serious problems will develop. The plan may even be quite conservative based on actual performance for other projects; it only becomes a matter of urgency when combined with some degree of technological uncertainty. Delivery urgency can be disruptive even when the initial delivery commitment can be eased, since much planning is done and work initiated predicated on the original date. A subsequent deferral then creates added costs.

Technological uncertainty is created by the need to accomplish a considerable degree of advance in state of the art (SOAA), and intensified by a high degree of interrelatedness in the design and in the production process.

The degree of SOAA obviously has a direct impact on the degree of uncertainty in the project. High interrelatedness has also, by making it difficult to anticipate the implications of a design change through many areas of the design and production processes. But perhaps the most profound impact of interrelatedness lies in the sheer work and time required to trace these effects, and in the enormous possibilities for disruption of the production operations underway whenever a design is delayed or changes are made to it.

- Advance in SOA -

Defining the degree of advance is difficult, if for no other reason than because the technological improvements planned for or required by a program are often not understood to be so substantial as they turn out to be. SOAA is difficult to quantify, and so to explain in concrete terms to anyone but an expert. At the same time, the experts pride themselves in solving difficult problems and so tend to be optimistic.

It is becoming possible to supplement our somewhat intangible sense of technological gap by developing concrete definitions of objective product characteristics and performance levels, and important steps are being taken to establish quantitative measures of SOAA*. However, there is still great danger in starting a new product development that its degree of SOAA not be appreciated. This prevents proper identification of the areas which might offer difficulty, and so require new personnel and other resources as well as suitable alternatives. It also limits the establishment of suitable warning devices that trouble is brewing.

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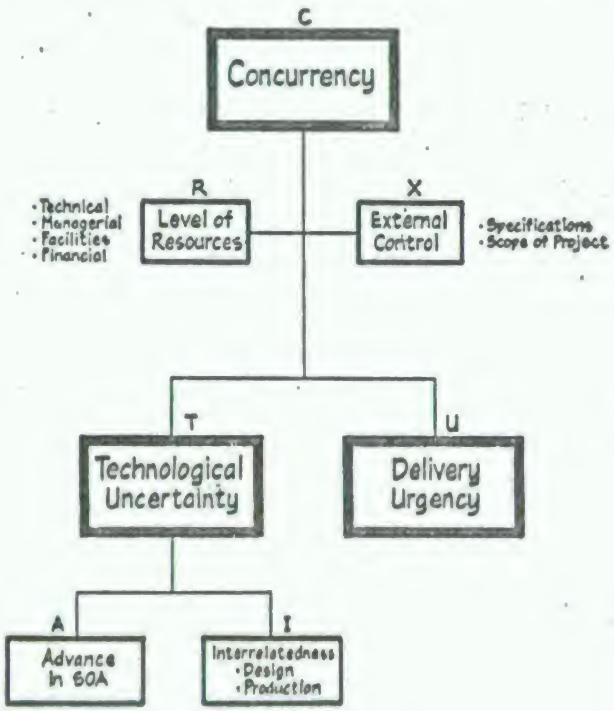
Note: * Selected readings, Items 5, 8, 11, 17, 19 and 21. For an early effort at rating SOAA see Item 11, page 13, while Item 19 represents a fairly mature application of the technique to aircraft turbine engines.

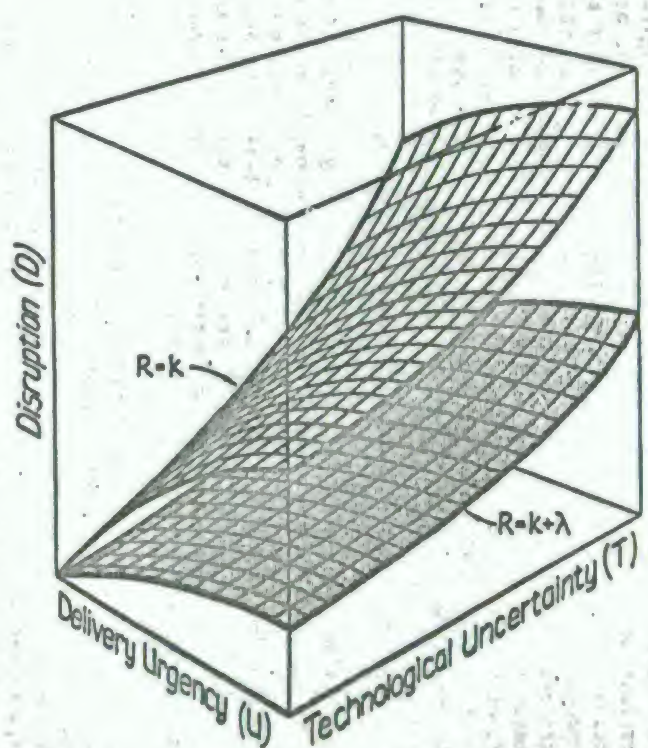
FACTORS IN CONCURRENCY



$$C = \phi\,(A, I, U, R, X)$$

Exh. II-A

DISRUPTION MODEL



Exh. II-B

- Interrelatedness -

If the degree of SOAA is the fundamental driver of technological uncertainty then interrelatedness is a major multiplier of its impact on cost of development and production. Interrelatedness of design boils down to the fact that a change in one component or subsystem affects many others, and of course this process can iterate further. Interrelatedness can also affect production and vendor activities, since a change in production methods or delivery cycle in one area or component (generated, of course, by design delays and changes) may affect production of other components or work in other production areas. Again the process can become very complex with many ripple effects. In general, a product operating in a more advanced area of technology will be more subject to interrelatedness. Aircraft and ships provide good examples of great interrelatedness in design, but there are many others.

Interrelatedness in the production process has many causes and effects. For example, a different sequence of production operations may be required when several components become integral parts of a major assembly. A change in sequence for one component may require sequence revisions in several others to balance shop activities. Or, a different process may be necessary because new materials are used (say titanium instead of steel) or a design change requires tolerances which demand new production equipment and techniques of quality control.

The interrelatedness problem is probably best visualized in terms of a comprehensive PERT network. This network links, first, all major components of the product to show the cross fertilization of design concepts and requirements. It then proceeds to the production process to show its intricate sequencing and its close relationships to design release dates. Attention to life-cycle costs, of course, extends the network of interrelationships into areas of operating costs and field support facilities.

- Compounding Factors -

Two major factors compound the disruptive effect of sheer concurrency: First, the level of resources effectively available to the project and second, the degree of external control over events. The level of resources comprises all types of resources — technical, managerial, facilities, financial, etc. Adequacy of the level is measured by what might be termed "organizational slack". This condition is not easy to define precisely, but two characteristics seem of primary importance.

One is the organization's experience in the basic technology involved. This provides an invaluable fund of knowledge and skill in handling the inevitable unexpected problems which arise, and which could very well swamp an inexperienced organization. A second is the degree to which the task at hand fully engages all resources reasonably available over the time-frame of the project, leaving inadequate strategic reserve for use on unexpected problems. This can be a critical flaw, given the intense time compression inherent in concurrent design and production.

Keeping the project small in relation to the overall organization increases the amount of slack available for emergencies, provided it does not encourage assignment of inadequate managerial talent and other resources, as it may in a large organization. On the other hand, minimal slack limits the ability to cope with complex requirements or with unexpected variation, and increases the likelihood and the cost of disruption. There is strong analogy with the queuing approach to meeting random demands by use of adequate float.

The degree to which external constraints are imposed on an otherwise normal process of product development can also intensify disruption. One frequent problem is the need to incorporate design changes according to the customer's evolving

concept of the end unit and its uses. Others include the need for protracted outside reviews, for the product to interface with other products also in development or to accelerate certain phases for political reasons.

- A Preliminary Model -

Exhibit II-B shows a speculative model, for illustrative purposes, of the impact of these various factors on cost. Disruption cost is pictured as a curved surface, its value increasing monotonically along the axes of technological uncertainty (T) and delivery urgency (U). One cost surface is defined for each given ratio of resources to tasks (R). These surfaces have the property that as the resources ratio rises the cost surface rotates downward. Considerable work has been done to measure the relationship of disruption cost to other factors. However, it is premature to propose general functional characteristics.

2. How Concurrency Develops

- A Frequent Pattern -

Concurrency is injected in many ways, often without being detected in advance. One all-too-common scenario may help us sense the reality of the problem. This example is not an academic one; it represents actual situations which have been observed a number of times and in different industries.

The enterprise embarks on a program requiring the delivery of a specific product within a specified time period. While the product is not fully designed, it is soberly judged to involve only existing state-of-the-art, familiar to the organization. Nevertheless, serious technical problems arise. These require extensive time to resolve plus substantial changes to the original design and production procedures, and schedules and costs increase substantially.

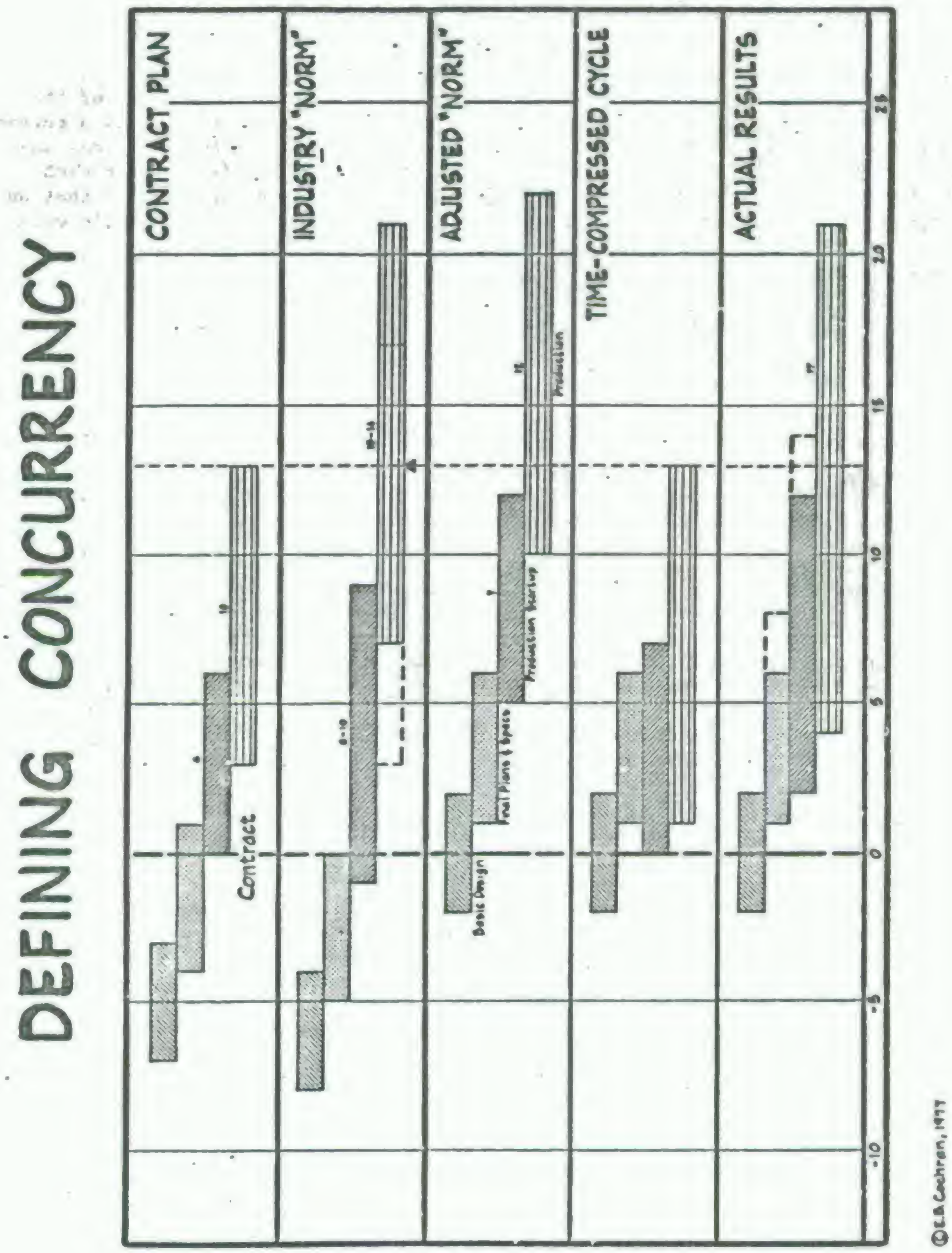
Intensive efforts now must be made to minimize deviation from the original delivery schedule and product specifications. This further increases costs, as the confusion caused by change is compounded by the need to expend greater effort in the time still available. Much interaction occurs among the various stages and events of such a situation and the end result can be a cost overrun of monstrous proportions.

A fair share of the problem occurs because of limitations imposed by the tight delivery requirement. Such a constraint, together with the delays which occur and the added tasks which must be performed, cause a "time-compression" effect. This acts like a reflector behind a fire to intensify the effects of change on the cost of the program. Without the delivery constraint cost increases might be far less, since production and other activities could be suspended until development milestones are met.

- Four Steps from Design to Delivery -

Exhibit II-C carries the example a step further by comparing the original contract plan in very schematic terms with the results of a more realistic appraisal of the situation and with the final disastrous result. The vertical heavy dotted line to the left of center represents the actual date of contract for the program, and the horizontal scale at the bottom is calibrated from this point in

Exh. II-C


DEFINING CONCURRENCY
CONTRACT PLAN
INDUSTRY "NORM"
ADJUSTED "NORM"
TIME-COMPRESSED CYCLE
ACTUAL RESULTS
Contract
Basic Design
Final Plans & Specs
Production Startup
Production
-10
-5
0
5
10
15
20
25
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increments of five periods in each direction, positive to the right and negative to the left.

Each of the five charts shown in the exhibit contain four basic stages, represented by bars of different patterns. The first bar is for "basic design", which entails all fundamental decisions on design and major production processes including necessary prototypes and other tests. The second is for "detailed design" in which final plans and specifications suitable for use by a manufacturer are prepared. The overlap between these two stages involves only items in which the work continuing in the first stage will have no material effect on the work already completed, and so will not obsolete work under way in the second stage.

The third stage is termed "production start-up". It is the period during which the organization translates the plans and specifications into working drawings suitable for use by vendors and shop personnel, develops detailed production methods and tooling, prepares detailed plans for production, establishes its vendor support and issues necessary purchase orders, plans necessary facility enhancement and organization changes, and then implements its plans for an orderly start of production. The fourth stage is the production cycle itself, ending with delivery of the first unit for a large complex product, or the first significant lot of units for a smaller product.

- The Mechanism of Concurrency -

The first of the five charts shows the overall contract plan. Note that the design phase of the program is considered to be essentially complete at contract time, with only one time period remaining for cleanup of the detailed plans and specifications. The third stage, involving preparation for production, allows six time periods and can overlap slightly with preparation of final detailed plans. Some overlap with production is also permissible if done with close attention to the detailed precedence relationships inherent in the production process. A delivery date of thirteen periods from contract is achieved.

The second chart displays a normal industry pattern for the development and introduction of products of this type. While similar to the first chart, it shows a range of times for production start-up activities since a product similar to those which a company has been producing will allow some reduction in cycles. Note that contract go-ahead is not set until final plans and specifications are complete, but a small degree of production start-up is allowed before contract due to the small risk. The minimum industry delivery cycle may then be computed at sixteen periods. Allowing for the overlap of start-up with design and production, total flowtime shrinks to thirteen periods, the same as in the contract plan. The company's contract plan seems attainable, presuming close similarity of the product to its experience and no substantive design problems.

The third chart shows the results of adjusting the industry norm to what proved to be the actual conditions of the project. First, it developed that the product was by no means out of the design stage, and in fact had not completed the basic design stage; this moves the entire plan five periods to the right. The characteristics of the product then turned out to require a production startup cycle of seven months rather than six as planned, and twelve months for production rather than ten. With suitable allowance for overlap, the adjusted delivery date becomes period twenty-two, nine periods and seventy percent later than contract.

The fourth chart, "Time-Compressed Cycle" shows vividly the results of

squeezing the realistic requirements into the contract time span. It is apparent that the contract contained the seeds of disaster. Basically, the design time cannot be shortened. Nevertheless, production must begin only one period after contract to meet the delivery date; thus, startup must begin immediately.

- The Inevitable Disaster -

The last chart, "Actual Results", indicates a typical outcome. Due to the confusion resulting from premature demands for production start-up, the design process itself may even take longer than normal, as indicated by the dotted extension of the second stage bar. Startup simply cannot begin immediately and also extends longer than normal as design delays and changes affect vendors, tooling and shop operations. Thus, the company could not start production until four time periods after contract, even later than the original contract plan.

The production cycle then expands from twelve to seventeen time periods, reflecting its premature start and the serious and repeated disruptions of its orderly development. Hence delivery does not occur until period twenty-one, an extension of sixty percent over the contract requirement. Actually, this is a pretty fair performance in view of the fact that a realistic estimate was for period twenty-two. The company performed heroically to accomplish what it did, but at dreadful cost.

4. <u>The Product Development Process</u>

Development, or design, was defined above. We shall now describe the process itself in some detail, as an aid to establishing the sources of cost overrun and how they operate. In so doing, we shall focus on "incremental" development, previously described as the most economical procedure, to provide a suitable basis for evaluating costs of concurrency.

- The Incremental Procedure -

Simply stated, this involves a number of discrete phases or stages, linked by decision "nodes".* That is, each stage must be completed before it is decided to undertake the following one. Basically, this requires: (1) separating development from the subsequent production of systems; (2) first performing those aspects of development aimed at demonstrating performance, then proceeding to such matters as reliability and maintainability; and (3) periodic assessment, redefinition and readjustment of program cost, product performance, schedule and the need for further technical advance.

Such a procedure has long prevailed in consumer product industries. New drug and chemical products customarily require a "pilot plant" stage, while many aircraft engines and entire aircraft (the Boeing 707, for example) have benefited from a two-stage process in which the first stage is a sizable (non-incremental) military contract. Incremental development also has been widely used by European governments to control the development costs of sophisticated weaponry, and a similar procedure has again been applied in U.S. defense procurement ("fly before you buy").

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<u>Note</u>: * See Selected Readings, Item 11, pp. 41-54. Incremental development is also referred to in Item 4 as "sequential learning".

- Stages in Incremental Development -

Exhibit II-D describes the product development process as essentially composed of six stages. We shall briefly describe these below.

Stage 1:

The objective of basic research is simply to develop general knowledge which may be applicable to a wide variety of product types, perhaps even in a very indirect manner, and for a variety of industries. Applied research, however, is directed toward development of a specific class or type of product, and essentially determines the technical feasibility of that product.

Stage 2:

Basic product planning is performed after the results of applied research indicate the technical feasibility of a potential product, and proceeds to determine its general commercial feasibility. Should the product pass this test it proceeds to...

Stage 3:

Prototype development, which will now determine the manufacturing and operational feasibility of the product. During this, many unanticipated questions of design, construction, test, producibility and customer evaluation are faced for the first time. Again to quote a key reference*, a prototype is:

> "a full-sized, or nearly full-sized, model that can be tested in the true physical environment in which the final product will be used... It will generally be built with a minimum of capital equipment...(and) can be either a subsystem or a collection of subsystems, depending upon the needs of the development project...(It) will determine the feasibility of a design and resolve the uncertainties surrounding its performance. To a lesser degree it will tend to resolve the cost uncertainties surrounding the manufacture,...(which awaits) actual construction of the capital equipment needed..."

Stage 4:

If the project now passes another comprehensive program evaluation, we move to...

Stage 5:

Detailed program planning. The first step is to prepare the complete final design. Then, a detailed examination is made of all steps necessary to produce and market the product. That must be done in considerable detail, to ensure that the production and marketing organizations can handle the task in the time required. It is a truism that any sound estimate of cost, and therefore decision on price, must be based on a valid master plan of event.. Obviously, such operating plans must be predicated on firm design and specifications.

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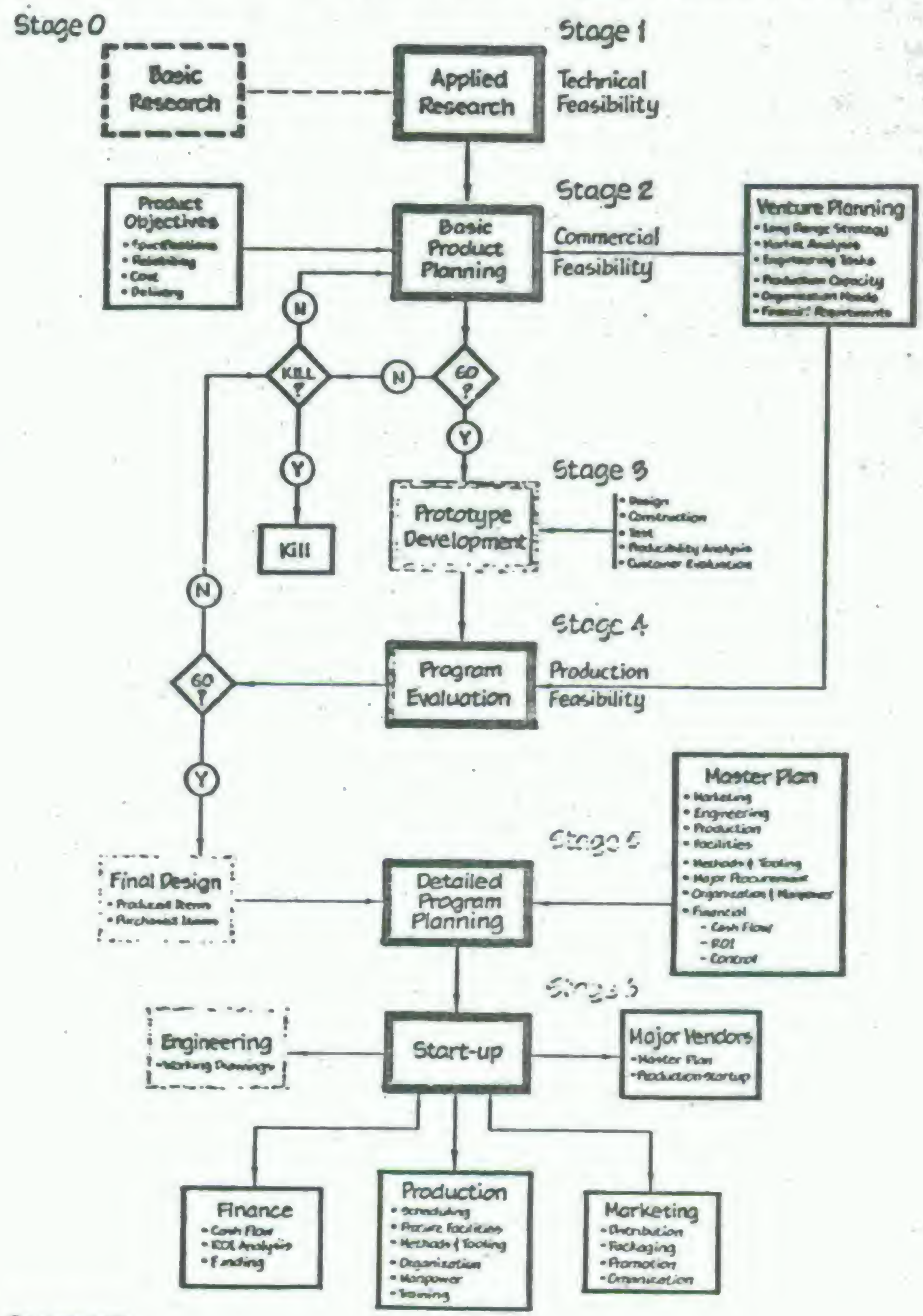
Note: * Selected readings, Item 4, page 27-28.

STAGES IN PRODUCT DEVELOPMENT



Stage 6:

Once a detailed master plan has been prepared on the basis of the final design, a valid decision may be made to proceed with the start-up of production and marketing activities. We then move into the start-up of production, vendor procurement and marketing, sometimes termed the "administrative leadtime". One important phase of this is the development of "working drawings" necessary for the production and tooling operations.

Experience shows that we must be quite clear about the distinction between "product development" and the "development" of working drawings. The former results in a final design and specifications with proven capability to produce. The latter merely requires engineers from the production organization to employ those plans and specifications during the administrative leadtime to develop the detailed drawings and other working materials required for full-scale production.

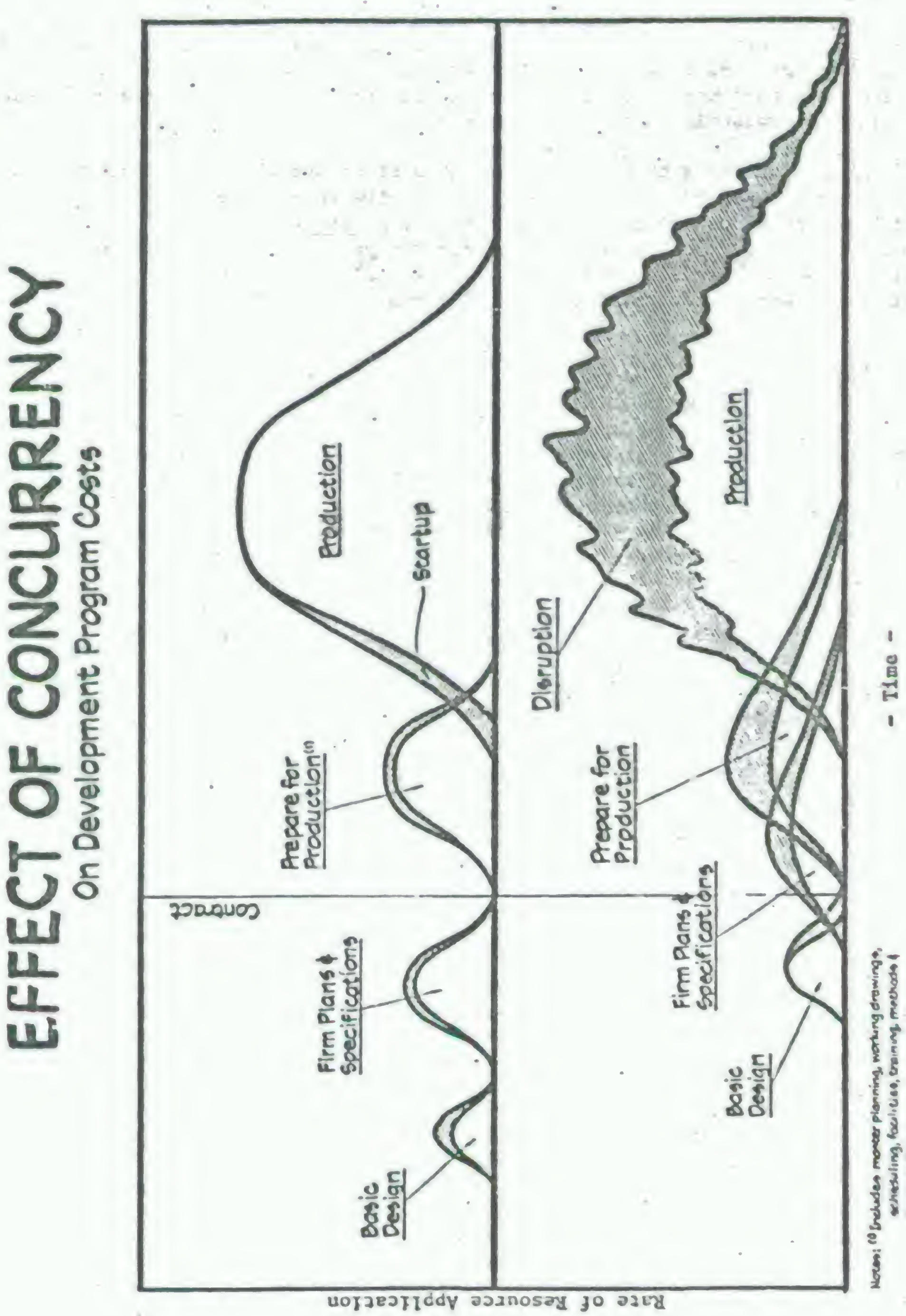
- The Effect of Concurrency -

In Exhibit II-E, the upper section illustrates the essential results of a fairly orderly incremental procedure, in which the activities of a basic design, development of firm plans and specifications, and preparation for production are generally sequential with little or no overlap between them. For production activity there is somewhat more overlap, but this is restricted to functions in which the preceding activities do not affect the production functions concurrently underway. In fact, some overlap between the first three activities could also occur, provided that there be no results in one of them which could affect earlier results in a succeeding activity.

Each activity has some degree of cross-hatched area in it. This roughly represents the fact that some of the work must be discarded because it represents the results of false starts, correction of errors, etc. Such costs are, of course, normal for product development and introduction.

The lower chart indicates some effects of concurrency, due to more overlap between the various stages than in the upper chart. The white area on the second chart roughly corresponds to the total area on the first for each function. However, there is now shown, by cross-hatching in a different direction, certain added costs for each function. These new costs may appear even in the basic design activity as a result of haste and shortcuts taken to meet the tight deadline. In addition, starting the development of firm plans and specifications before the basic design is completed (with appropriate tests) increases the amount of second phase work obsoleted by the errors normal to basic design effort. The need to meet an urgent production deadline requires extra effort in the same timespan and this condition cascades into subsequent activities, increasing the amount of mistakes and rework.

The final result of the concurrency is that production does not have a reliable design available in a timely manner. Hence its choice of methods, processes, vendors and tooling is unreliable, as well as any plans for manpower and material buildup and use. In turn, this unreliability infects the choice of production facilities, plant layout, production sequences, mix of worker skills, and balancing of production lines and work-in-process requirements. The degree of these effects is much increased by substantial interactivity among drawings and among production processes, as well as between production, procurement and design activities.


EFFECT OF CONCURRENCY
On Development Program Costs
Rate of Resource Application
Contract
Basic Design
Firm Plans & Specifications
Prepare for Production(1)
Startup
Production
Basic Design
Firm Plans & Specifications
Prepare for Production
Disruption
Production
- Time -
Notes: (1) Includes master planning, working drawings, scheduling, facilities, training, methods & tooling, etc.
© E. B. Cochran, 1976

Many types of disruption cost may be important in a given circumstance. Other than labor hours, some five main effects of design delays and changes generally require close attention: increased labor rates, greater overhead, extra material cost, financial costs and cost impact on other projects. However, such a short discussion as this cannot hope to cover them all with any degree of thoroughness. We shall therefore focus our attention on labor hours.

5. The Mechanism of Disruption to Labor Hours

Concurrency disrupts production labor through the design delays and changes which occur. Their presence indicates a degree of immaturity in product design which leads to unpredictable effects on production.

Efficient production demands specific disciplines concerning schedule, methods, tooling, manpower application and material receipts. Proper balance in these matters creates momentum and rhythm in the production process. Their absence creates frustration and a general malaise in the production process. Design uncertainty is an efficient tool for destroying production discipline. Many plans cannot be completed and those made cannot be implemented, while the work that can be started is continually interrupted and complicated by unpredictable changes.

- Design Delays -

The delay of most interest to us occurs near the beginning of production or after it starts; a delay well before production is due to start permits rescheduling or even cancellation at minimum loss. Significant delays may suspend or defer shop or vendor activities, perhaps causing layoffs with associated loss of learning. They may delay hiring, creating imbalance in a carefully planned build-up of skills and personnel assignments, extending the period of training for new employees and generally preventing the organization from reaching the "rhythm" necessary for efficient performance.

Since delay requires the shop and vendors to "work around" the problem, it forces revision in production sequencing. That creates interference with other work, greater worker movement, idle time and perhaps revisions to methods and tooling. These consequences dilute the effectiveness of shop control procedures and complicate material planning and inventory records. Frequent shop delays increase day-to-day variations in workload, reducing a supervisor's ability to measure the effectiveness of his subordinates and hence control them, and causing expensive duplication of setups.

Compounding all this is the shop's need to accelerate its work once the delayed design is received using long hours, overmanning and inefficient methods to minimize the delay. The results might, on occasion, be impressive. But the cost is always excessive and the organization is whipsawed as it shifts back and forth from underuse to frantic effort.

- Design Instability -

Even changes in product design that occur well before production starts can be disruptive. For example, a major growth in design and introduction of a radically new production process may require serious revision of the company's

production plan. Further, any change to one major component or subsystem might have complex effects on others, with other consequences that are hard to predict. All this disrupts both the design organization and the procurement process.

Design changes that occur after production begins have many additional effects. First, they often delay other work, creating the delay effects described above. Second, they cause direct loss of learning, since a task already performed several times is replaced by a new one. Third, the personnel affected by a change are slowed down. This puts them out of phase with others working alongside them, often slowing those others as well; at best, an inefficient realignment of workload may be required.

Fourth, design changes may require changes in production methods, which in turn require new tools, facilities or labor skills. This may also require extra training, causing further delays. Fifth, a change involves variable and nonrecurring labor tasks for different units (since they depend on the stage of completion reached) which are inherently more expensive to perform. Further, rework or retrofit of units already fabricated or assembled generally is done under unfavorable conditions because the affected unit has proceeded to a new location not so suited to the work.

Sixth, change costs are difficult to estimate because the changes are intricately involved with other work and require revised sequencing of subtasks and complex teardown and rework. Rarely is there any comparable experience available for the new tasks involved - usually the primary source of estimating accuracy. All this makes budgets unreliable, which weakens management control. Seventh, it is often impossible to segregate the actual costs of making a change. Even if this can be done, many changes require a vast number of cost accounts, complicating the supervisory task and providing numerous excuses to workmen for poor performance. Hence, introduction of many changes weakens floor budgetary control over recurring tasks, even if budgets can be accurately estimated.

Eighth, a design change may produce <u>growth</u> to the product itself, increasing the production task. This becomes disruptive if it delays production, conflicts substantially with the company's planning, requires more manpower or facilities, changes methods or affects supplier deliveries. And ninth, many changes directly affect the cost of performing other work which itself, theoretically, is not changed at all. The change and its rework requirements may affect the sequence of a large number of operations, the availability of certain facilities and demands on critical skills, supervision or storage space.

It is also true that numerous "small" changes are likely to be disruptive. For each one still requires extensive paperwork and review by many responsible people in the design, production and procurement organizations. One small change can, for example, affect a single part which appears on many drawings, or which is used in many places on the product.

- Implications and Ripple Effects -

There is an important further consequence. Taken together, cost increases due to disruption produce a sizable increase in the production task. This is true even when we exclude those task increases produced by <u>design</u> growth. It might be said that such task growth is, in a real sense, "normal" when fixed

production schedules are established on the basis of an unstable design. Once the production process is set in motion, it is not possible to delay and change designs without expending additional labor and other costs.

Thus, the plant finds itself operating at manpower levels well above those anticipated in designing the facility, planning the workflow or selecting equipment and tooling, with a growing inefficiency which compounds the cost of other disruptive events. The various forms of task growth interact among themselves, as the confusion bred by delay and change feeds on itself. Orderly planning and control procedures take time to perform and quickly fall behind the pace set by rapid changes to product design or production methods, or the need to recover time lost by design delays. The disruption taxes supervision to the point that major changes in organization and size become necessary, but it always seems to take a long time to locate, select and train good supervisors. In the meantime the labor force continues to grow, the existing cadre is spread even thinner and efficiency deteriorates further.

The degree of production disruption may be somewhat mitigated by relaxation of the delivery schedule to accommodate the delay or change. When this cannot be done, a "time compression" effect can multiply the disruption cost, as described further below.

- Time Compression -

Time compression (TC) occurs when an organization has insufficient time to perform a prescribed task with the resources available. Given those resources, TC is the result of an imbalance in the ratio of time to task through having either less time or more task. TC can affect any type of organization: design, production, marketing, administration or a combination of these. The urgency of meeting a schedule dictates additional costs in order to recover lost time or to expedite matters. More generally, TC creates cost by changing the time-cost trade-off relationship and by creating confusion and inefficiency.

For example, TC may result from the decision to shorten a product's delivery schedule because a customer insists on tighter delivery cycles than normal or on accelerating an existing schedule, or because the manufacturer wishes to capture new business. Then again, TC may result from underestimating of the development or production task to be performed, a reduction in tooling or procurement time allowances or the desire to increase product quality or performance by design improvements without allowing more time for delivery. However, given standard products, experienced manufacturing organizations can estimate their production costs and time-cycles with considerable accuracy. Since it is then easier to resist competitive pressures for unrealistic delivery date, they rarely experience TC.

As we have seen, concurrency of design and production sharply increases the amount of labor expended, which constitutes a task increase. Without schedule adjustment, therefore, concurrency creates time compression. This intensifies the effect of cost increases directly due to design delays and changes. In the development phase, the inevitable design difficulties directly increase the task to be performed, while delaying its completion. A similar process affects production. The design delays nibble away at the time available, while both delays and changes increase the labor task in ways we have described. Time compression occurs on both sides of the time/cost ratio. Costs are further increased by efforts to recover the lost time and to perform the added tasks without further delay in delivery.

Technically, some disruption due to design delays and changes would occur even if the delivery schedule could be relaxed. This specific cost might be termed the pure cost of design uncertainty, with only the increment caused by schedule recovery efforts attributed to TC. But it is generally impossible to separate the two. Further, once an organization embarks on a major project, changes or delays in any area must be incorporated expeditiously and the time losses recovered, merely to minimize disruption of other areas.

- Diagramming the Disruption Process -

Exhibit II-F displays the manner in which design delays and instability disrupt the production process. The process is complex, and the cost consequences may have multiple and interacting causes. As a result, it is not simple to determine or to measure disruptive effects of specific design events. An animated three-dimensional model also has been developed, which is of considerable help in visualizing the convolutions.

No attempt has been made to diagram the enormous complexity which actually exists when numerous interrelated components and production processes are involved. The flowchart is, however, a useful basis for more detailed study of disruption costs employing computer modeling techniques and further work is continuing to incorporate other cost categories.

III. MEASURING LABOR DISRUPTION

1. Basic Measuring Techniques

- The Normal Cost Pattern -

The products involved in concurrency situations are generally advanced in technology and thus complex in their configuration and manufacturing processes. As a result they involve long-cycle production operations, so their manhours follow a cost improvement pattern. Exhibit III-A shows the basic pattern, both on arithmetic and logarithmic scale. The first shows the rapid reduction of unit hours, at a decreasing rate. The second indicates the linear appearance of this cost pattern when plotted on logarithmic scale, and implies a constant rate of cost reduction between each pair of units whose sequence position is in the ratio of one to two.* Given a sound calculation of "should-cost" for only one unit, the existence of log-linear improvement is of great help in detecting the presence and measuring the amount of disruption costs.

Log-log graphs of improvement curve experience are particularly well-suited to expose the impact of disruptive events on labor hours. This has encouraged development of techniques to calculate the cost of such events, many of which have been known to practitioners of the IC art for a number of years. Reference (2) described these techniques at length, adding a number of refinements and new applications.**

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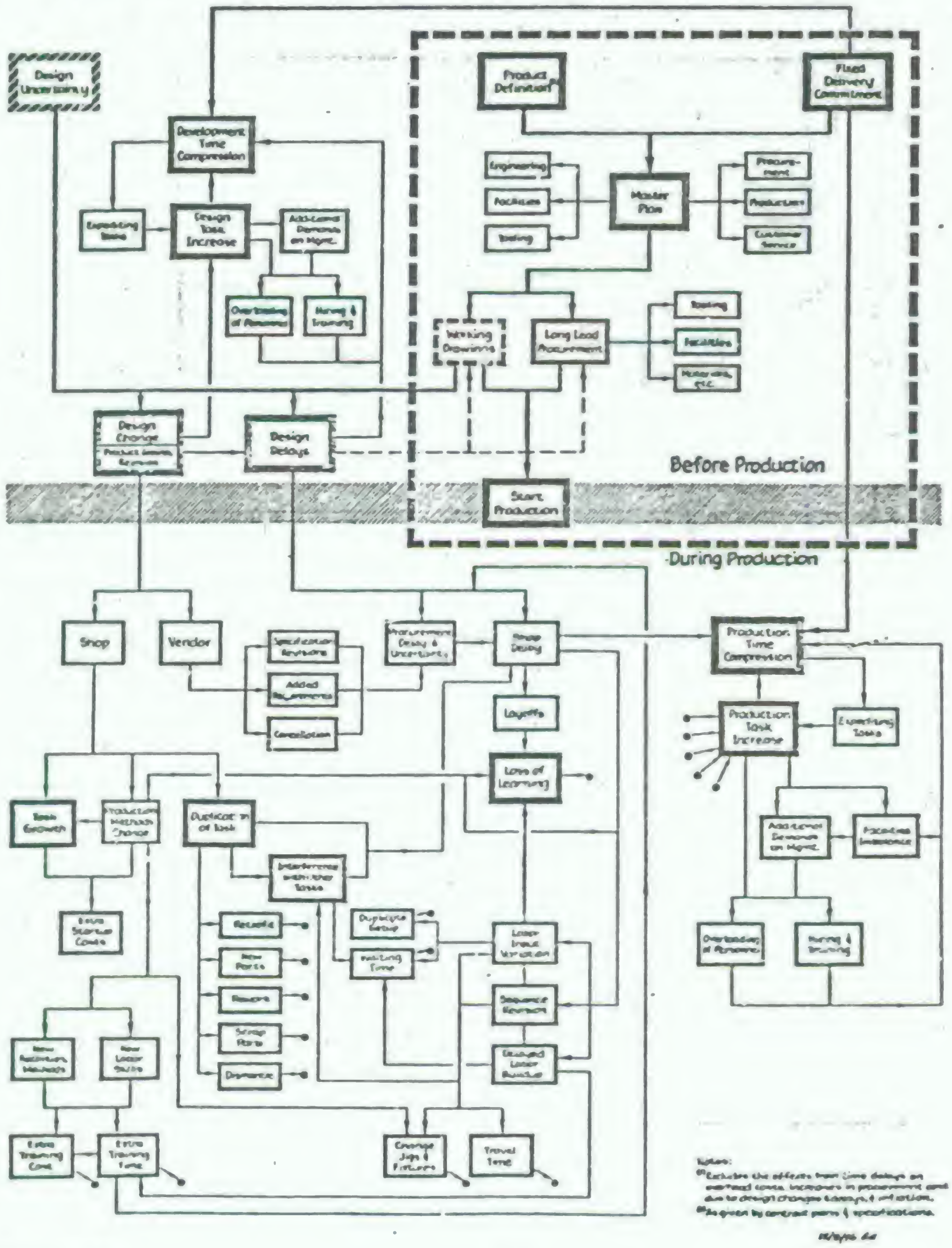
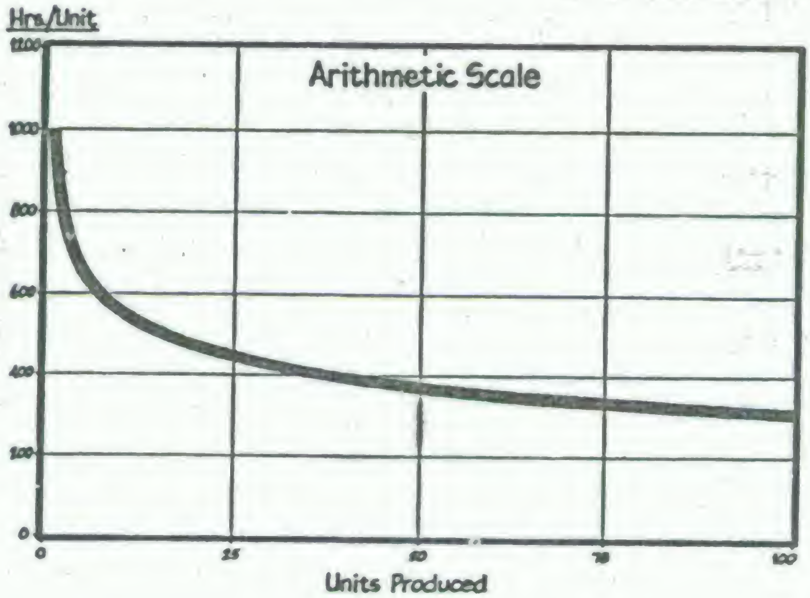
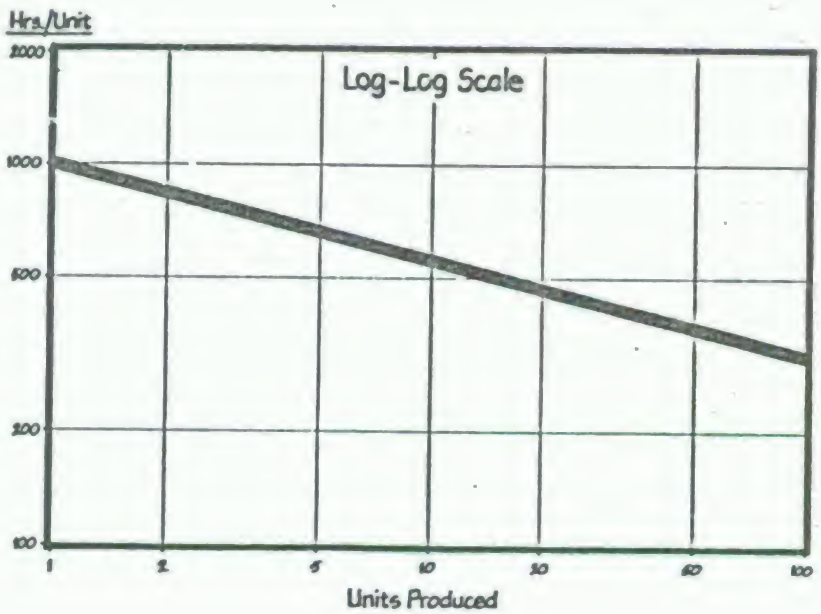
Notes: * The reader is referred to Reference (2), pp. 212-250 for further discussion.
** See pp. 285-396.

THE ANATOMY OF LABOR DISRUPTION[1]



THE BASIC COST PATTERN





When a significant change occurs for the costs of a task which follows the improvement curve, a substantial "blip" will appear on the regular downtrend of the cost line. The blip occurs because some work has been forced to return to unit one, so the improvement gained on the original task has been lost. The amount of penalty reflects the amount of the old task deleted and that of the new task substituted. Further application of this pattern to labor turbulence is described elsewhere.*

Another important disruption event is the interruption of production, which generates penalties upon the resumption of output. The traditional technique of evaluating this involves a "retrogression" approach, in which the penalty is calculated simply by assuming that the entire task retrogresses on the improvement curve sequence by a sufficient number of units to produce a cost increase of the appropriate amount. Subsequent units would then proceed from that position in the sequence in the usual fashion.

However**, this assumes that the recovery pattern will always fit such a rigid cost formula. It is more likely that a variety of recovery patterns occur, some more and others less rapid, as indicated by Exhibit III-B, which displays a range of patterns, from a rather sharp "scallop" shape for a rapid recovery, to a very slow recovery. Selection of the initial penalty, the duration of penalty and the shape of the recovery pattern are, of course, matters for careful evaluation. Recently, the appropriate calculations were reduced to a computer program to facilitate the estimation of these important disruption effects.

- The Conflict of Scheduling with Crew Size -

The substantial size and sophisticated design of many advanced technology products also means that considerable space is required to build them. This makes material handling expensive and places a premium on carefully planned material handling techniques. It also encourages the use of sizable crews of skilled people, who often move unit-to-unit more than the units move crew-to-crew. Hence, the development of production methods and sequencing is an important part of the planning process, and stable decisions here are essential to achieving reasonable costs. These procedures are strongly affected by substantial amounts of design delay and change. In order to measure the effects, we must first understand the elements of effective scheduling in the IC environment.

The improvement phenomenon means that holding crew sizes constant generates a continual rise in production rates. Thus, if the customer requires a constant delivery rate, shop scheduling is seriously complicated. One solution - to make periodic reductions in crew size - is damaging to production efficiency. The other - to buildup a large inventory of finished units - will allow meeting schedule during the early period of low output but require extra time and substantial investment.

This source of planning complexity and financial strain is compounded when fabrication and assembly activities, for example, each operate on different improvement slopes. The relative cost reduction from one unit to the next then is different between workcenters, and they get out of phase as one accelerates more rapidly than the other. A similar effect occurs when a workcenter's position in

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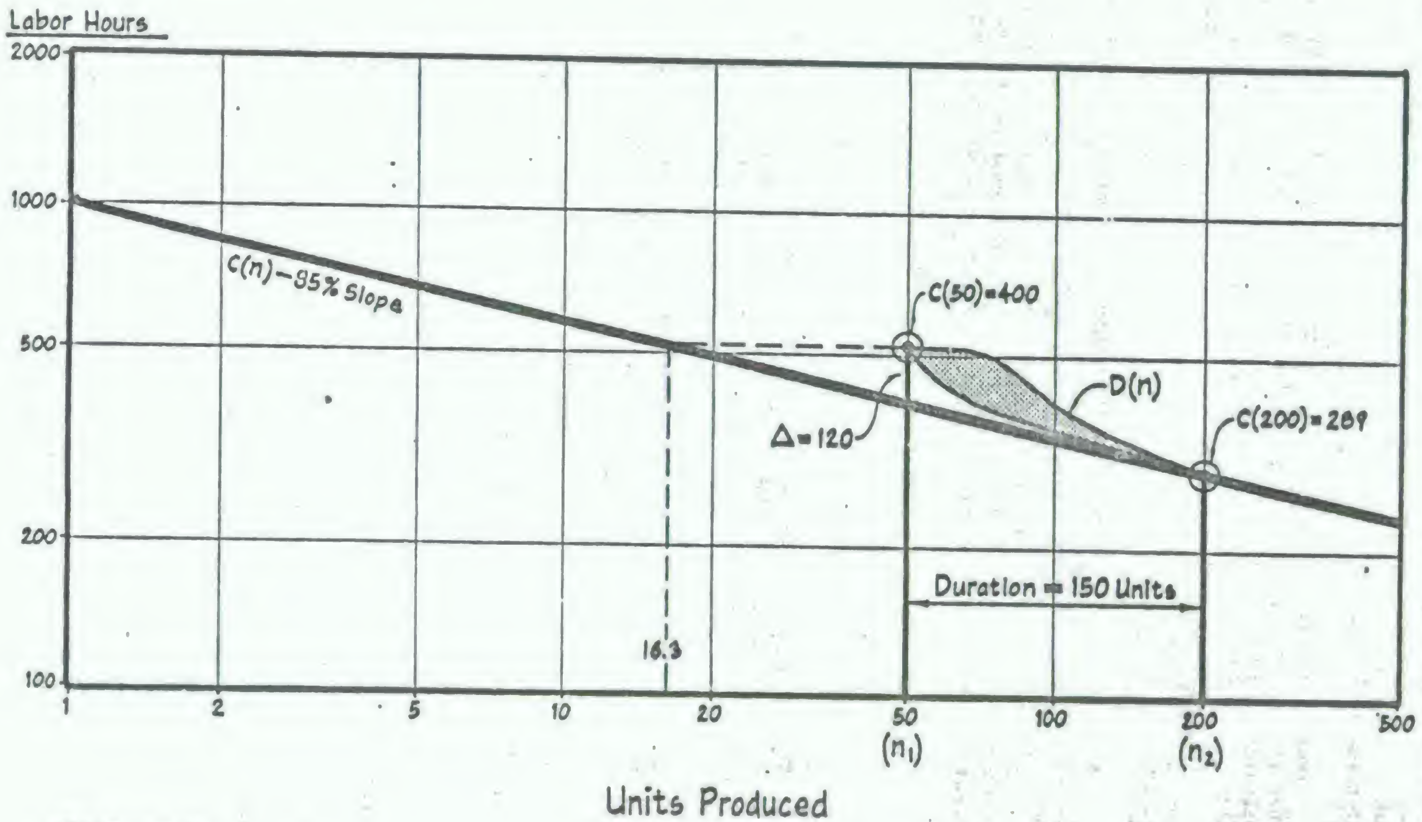
Notes: * See Reference (2), pp. 333-366.
** Ibid, pp. 367-396.

COST EFFECT OF PRODUCTION INTERRUPTION



Exh. III-B

the production pipeline places various crews at different positions on the unit sequence at a given time. It also happens when the output of some workcenters is measured by a different unit sequence than that of others, due to varying usage of each workcenter's output on the end-unit.

It is thus difficult but essential to establish work schedules and manpower budgets with two characteristics: (1) relatively stable manloading; (2) maintaining the cost improvement trend through acceleration of output rate, which means deliberate and consistent shrinkage of flowtimes for the various repetitive tasks. This requires careful activity analysis of the construction process in order to develop specific workflow directions for each crew. The lack of a moving production line makes such schedule disciplines of critical importance.

Activity analysis determines the basic flow of work, other than that performed on a converyorized or other such internally disciplined system. It aims at determining the most efficient sequence of major production events in view of the tooling, facilities and space available. To do this, it must assume well-defined methods, and focus on broad man-machine relationships and sequencing of major production steps.

Specific move dates for major assemblies and components can only be established on the basis of a soundly conceived and stable activity analysis. These move dates are fundamental tools of coordination and schedule discipline for numerous crews. By permitting orderly acceleration of output rates, they allow achievement of cost improvement budgets while minimizing changes to crew sizes and assignments.

The last step in the procedure - the workflow chart - requires solid accomplishment of the first two. It comprises the establishment of a carefully defined work plan for each crew's activities which itemizes all individual tasks and schedules them in an efficient daily sequence. It then assigns people to each task to ensure stable work assignments and conformation with established methods.

These three steps are closely interwoven and directly dependent on well-established methods, facilities and plant layout. That requires plans and specifications for the product to be firmly set well before production is scheduled to start. Thus, many changes to design cause serious loss of labor control which is compounded by the penalty costs which accompany task changes, personnel transfers and production interruptions.

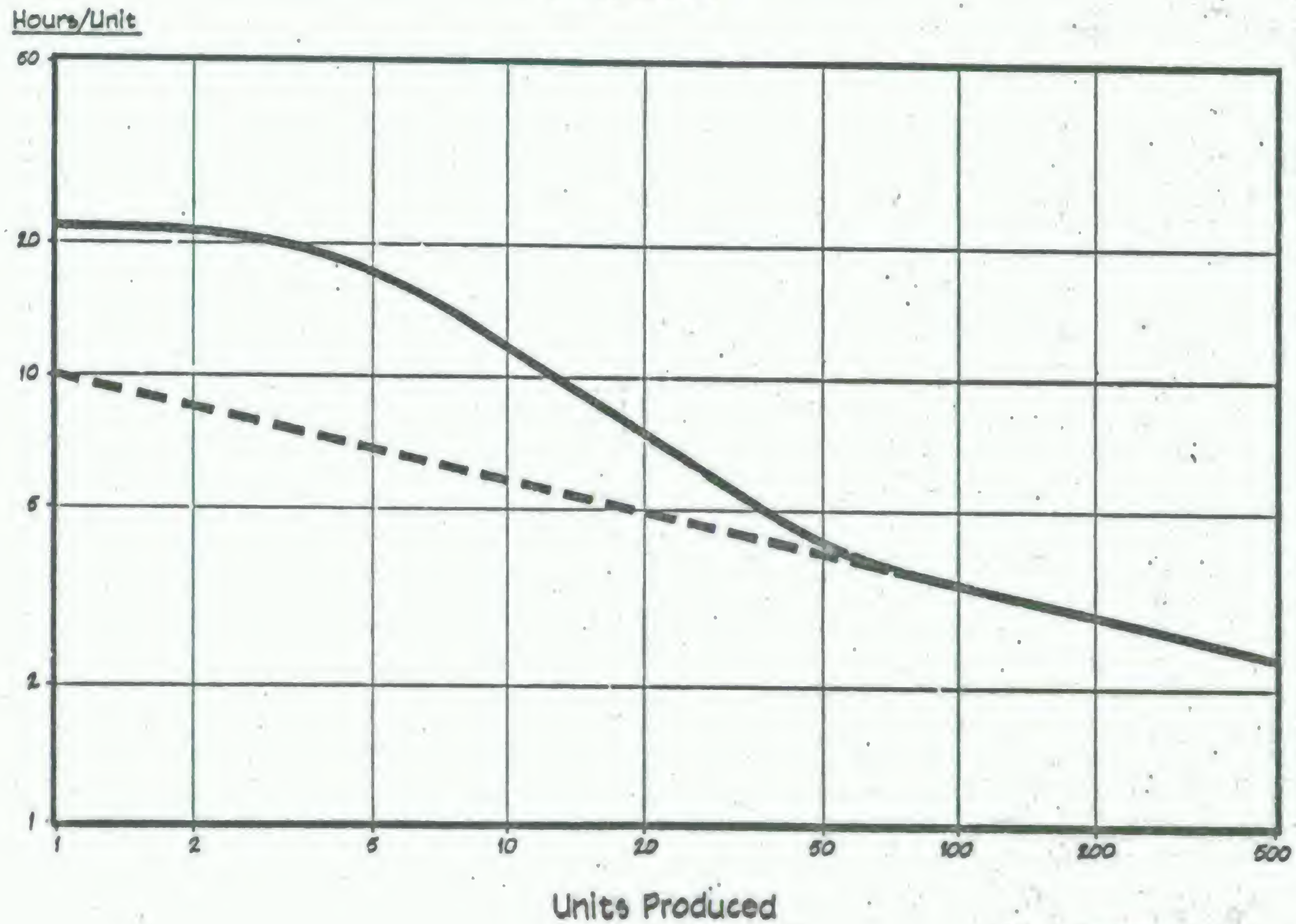
2. The S-Curve

We shall now discuss a method of formally estimating disruption costs, proposed in 1959[1] and developed extensively since then. This method, known as the "S-Curve", has been found applicable to a variety of production situations which involve long cycles for production labor, the same conditions as found for the improvement or "learning" curve. An example given by Exhibit III-C will be discussed later.

- Disruption and the Improvement Curve -

The improvement curve is sometimes used by mass production or "short-cycle" industries to predict the costs of introducing a new design into production. For various reasons (shortened cycle times, shallow slopes, low significance, accounting problems), the improvement phenomenon is considered to disappear during later stages of production.

THE BASIC S-CURVE PATTERN
85% Slope



Exh. III-C

For long-cycle products, however, the situation is more complex. Labor learning on new products continues almost indefinitely in a log-linear pattern, which reflects a rhythmic improvement involving six factors.* However, introduction of a new product causes additional cost above the normal improvement trend. The effect on direct labor hours is small for relatively stable designs and normal methods but much greater when the new product requires major methods changes with new tooling, extensive employee training and a protracted period of startup. This impact increases when the design is unstable and has to be debugged and changed during the production process, and again by design delays.

Clearly the S-Curve bulge is generated by the costs associated with design delays and changes. Some of these costs can be calculated by learning curve methods but many involve complex interactions not so easily captured.

The disruption goes well beyond the first few units produced. In a sense, the S-Curve is a decay pattern for disruption, and like going on a diet to shed fat, the process just takes time. The way production starts has much influence on subsequent units. Men work by example, and the procedures, tools and methods established during the first year carry forward to subsequent periods and units.

Design growth and changes require revisions to production methods and sequencing, and in facilities usage. When such revisions are introduced after production patterns are established, it takes much time and several units to implement them, plus the learning losses on those units. Many design changes occur after the affected components or operations are already completed, requiring ripout, rework and reinstallation. Failures of new components might require removal and rework of like items from subsequent units, and later reinstallation of a replacement. Intense efforts to minimize delivery delays require shifting people to the most urgent tasks, so that pipelines are drained and follow-on work neglected, causing re-start costs for subsequent units.

The time compression leads to manpower transfers from one task to another and back again, to relatively inefficient catch-up procedures, to over-manning, and to use of inexperienced people, to widespread overtime and so on. The need for such practices often continues to follow-on units in order to offset the delay effects of disruptive events. When many units are in varying stages of completion, all are affected by the disruptions operative at the time. Work in process is held up, and the inventory accumulation demands frequent rearranging to locate items currently required for the shop, and other double handling that affects all units in process. The clogging up of valuable staging areas and workspace interferes with work on follow-on units.

And finally, the cost increases generated by disruption severely increase the demands on management, stretching its capacity and reducing labor efficiency. It takes time to work out this effect. Even when new managers are acquired, labor efficiency must suffer during a considerable training period.

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Note: * See Reference (2), page 63.

- Size and Duration of the Bulge -

The "size" of the S-Curve bulge may be defined in terms of its initial height above the underlying linear improvement curve. Its "duration" refers to the number of units over which it continues. Bulge size can differ due to the intensity of the problems caused by design concurrency. Bulge duration is linked to bulge size to some extent, since a greater size inherently takes longer to work itself out. Recovery of the original trend line must proceed in a credible fashion; one cannot expect ridiculously sharp slopes.

However, other factors are important in determining the duration. One is the need to produce "enough" units. For example, the adequacy of tooling and methods, and the need for their correction, are determined partly by the evaluation of mistakes made or problems discovered during production. Hence, a sufficient number of units must be produced before all start-up problems can be detected and so resolved. A similar consideration applies to the disruption caused by design delays and changes. The discovery of some design problems occurs only as units have a chance to progress through all aspects of test and even into field operations.

However, adapting to circumstances of new product introduction is also a matter of <u>time</u>. For example, many new types of tooling, jigs, fixtures, work sequencing, control procedures and personnel skills must be absorbed by and into the existing organization. Related training and other activities take time to organize and conduct, as do the incorporation of corrections in tooling and facilities. Similarly, the discovery and correction of design defects requires careful study by engineers, the progress of which relates more to the capacity of the design organization than to the cumulative output achieved. The production organization also takes time to replace inefficient procedures initiated to work around a delay or to absorb the impact of an urgent change.

The close relationship of bulge size to the degree of concurrency - described briefly by Reference (2) as "time compression" - led to a description of the bulge itself as a "TC cost". Given a "standard" shape for an S-Curve of a given slope it is then useful to describe the bulge size in terms of a "TC-ratio" with a value of unity for the standard curve. While the degree of TC itself cannot be measured, its impact on a production organization can be described and its final cost effect measured in terms of the amount by which actual hours exceeded the base should-cost. Therefore, a manufacturing facility that experiences TC repeatedly can develop empirical methods of predicting its cost effects. In doing so, the degree of TC for a new product can be viewed in terms of the adequacy of the "leadtime" available to develop and introduce that product into production.

The question boils down to determining the degree to which several main operating functions can be done efficiently in the time available. Knowing the factors which control the performance of each function, we can study performance on past products and relate that experience to the degree of disruption cost which occurred, expressed as a TC-ratio. Then, for a new program having specified leadtime characteristics, we can predict its TC-ratio, from which the bulge cost itself may be calculated.

- Calculating S-Curve Patterns -

In recent years, computer techniques have been developed to permit easy adjustment of the S-Curve bulge for three conditions: (1) the slope of the underlying

linear improvement trend; (2) the degree of time compression effect or bulge size, as measured by the TC-ratio, and (3) the number of units produced before the bulge phases into the linear cost (bulge duration).*

An example of S-Curve patterns for a large product is charted by Exhibit III-D. It is based on: (1) an 85 percent linear cost trend, (2) an estimate that a 25 percent TC-ratio is required to allow for the labor cost effect of major new tooling and facilities on the start-up of a new product, and (3) a projection that the start-up effect will last for six units, in view of the time required to work out the resulting problems. The first curve above the linear trend (marked by TC of .15) shows the distribution of unit costs for a more modest (and more usual) start-up expense. Other curves show the effect of higher TC-ratios on initial cost and on bulge duration.

3. Further Confirmation of Disruption Effects

As stated earlier, it is rarely practical to identify r measure individual costs of labor disruption. Thus, in the past, the main means of measurement has involved broad comparison with "as-built should-cost" calculations, using S-Curve techniques to forecast the broad impact of concurrency on labor hours. However, with deeper understanding of the disruption phenomenon, we can now use three analytical techniques to demonstrate the consequences of concurrency in some detail. These are: variability analysis, network analysis and computer simulation.

The greater detail involved in such analyses provides more precise testing of our understanding of the phenomenon, while allowing us to prepare more accurate estimates of concurrency costs. They also have the interesting - and perhaps significant - quality that the further you go with any of these analyses, the more serious you find the consequences of concurrency to be.

- Variability Analysis -

Well-known techniques of measuring the effects of uncertainty have been used for some years under the heading of queuing theory. These clearly show the effect of random variation in, for example, the time a specific operation can start, or the time required for its performance. Such variability demonstrably increases costs for sequential operations unless suitable inventory or float is provided. However, this involves extra investment and increases the need for rework as a result of a design change. These effects are much increased as more operations are involved, or for large complex products which have limited room for float.

Such conclusions clearly apply to a situation affected by the unpredictable design delays and changes which result from concurrency. For they cause irregular delay of start dates, unexpected changes in task sizes and injection of rework and retrofit at unplanned locations.

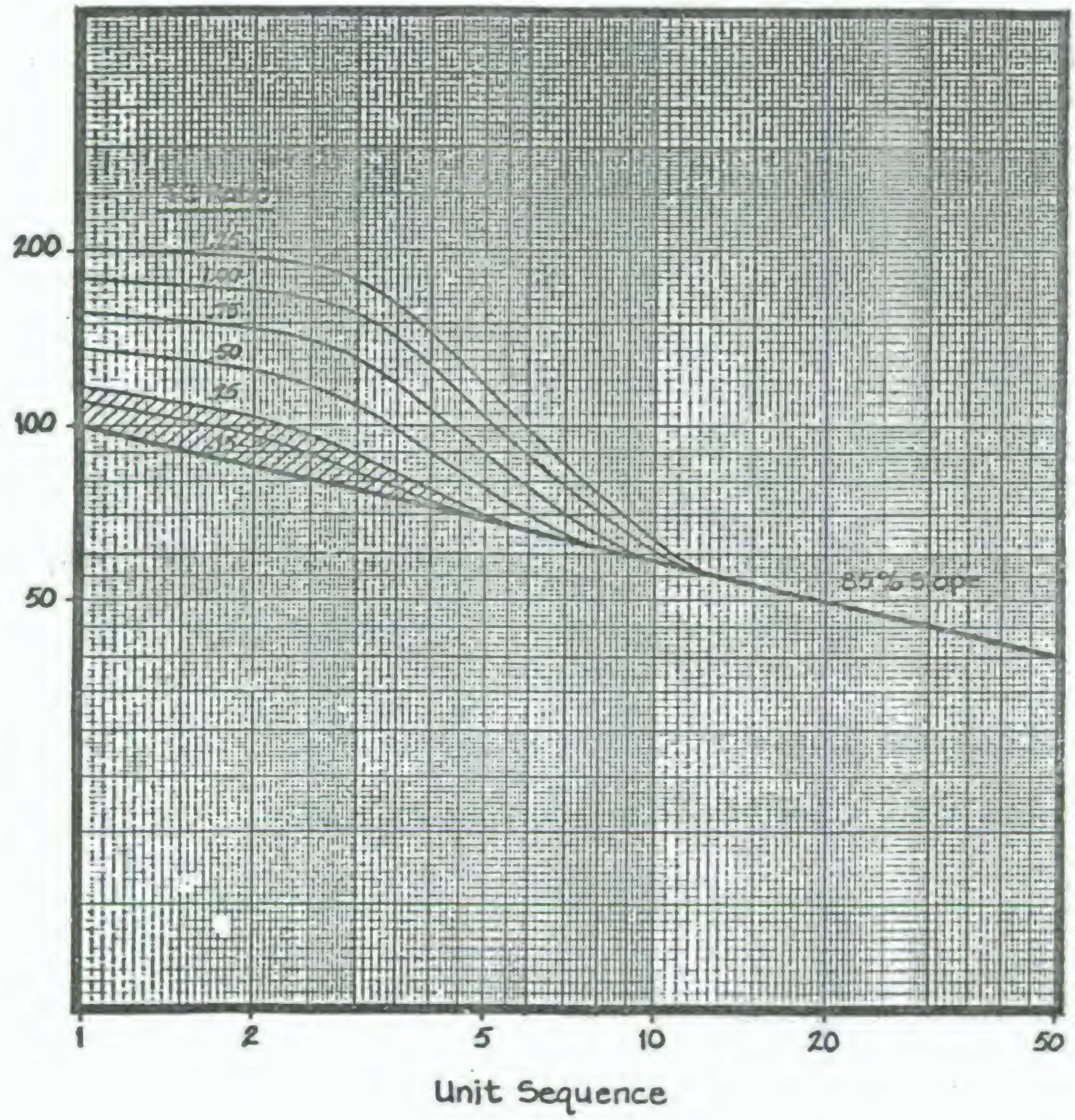
- Network Analysis -

This simply establishes three basic facts or estimates for each major task in a project. In approximate order of importance, these are: precedence relationships, task duration and resources required.

Note: * The original data for TC = 1 and a duration of 70 units appeared in Reference (1) and Reference (2), pages 160, 170 and 184. Subsequent computer refinements have altered the unit of measure in which they are expressed, but not the shapes.

BULGE SHAPE VS. DURATION

6 Unit Duration for TC=.25



Precedence relationships are defined by a diagram which identifies the complex interrelationships among design, tooling, procurement and production sequences. A simple example for building construction is given by Exhibit III-E. Even the most elementary diagram indicates how a design delay in one component can hold up design for several others - or subsequent non-design activities. Design changes will affect many tasks, thus changing methods, production sequences, facilities and tooling, and complex production planning then must be redone at considerable loss of time. Attempts to shortcut this re-planning are costly in labor.

Estimation of task durations is necessary to obtain certain important benefits of network analysis. These include projected delivery times, identification of "critical" activity paths (the sequence of pacing activities) and the possibility of switching effort from sub-critical activities to reduce the delivery cycle. These reveal further consequences of concurrency. For example, design delays in critical path activities will extend the delivery cycle. This generates pressure to meet the scheduled completion date by out-of-sequence work, increasing labor cost, and requires extensive replanning. Design changes increase many activity times and add new operations. This creates further pressures to meet schedule, despite the new work, and again requires extensive and time-consuming replanning.

Determining the use of resources (people, space, equipment) allows full development of a "rhythm" for the endeavor, and further reveals the devastating effects of concurrency. For example, design delays cause unbalanced demands on resources, causing layoffs and idleness, while requiring overtime and other acceleration costs to maintain schedule. Design changes further cause shifts in the amount and type of resources required, the effects of which are compounded by related changes in precedence relationships. Naturally, the penalty costs of concurrency revealed by network analysis alone are compounded by the variability generated by unstable design.

Network analysis may also be geared to actual dates of key events to obtain two further benefits. First, it helps identify production "compromises" or deviations from the "ideal" sequence used to offset (at extra cost) the effect of design delay and changes. Second, by using the "actual" network to spread "as-built should-cost" over time, it allows substantial measurements of disruption by area and time period.

- Computer Simulation -

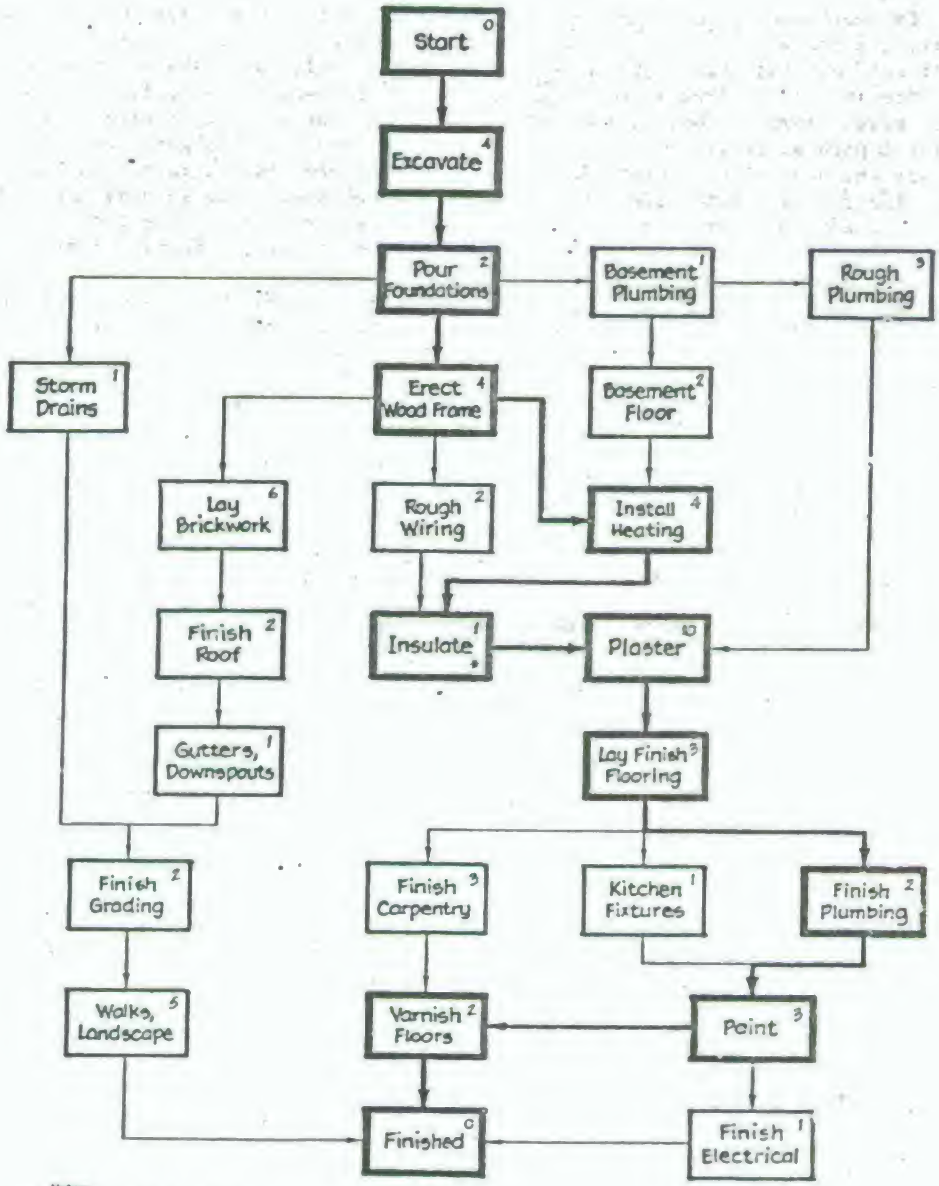
Full-scale modeling or simulation allows fullest use of variability and network analysis, and creates an important new dimension by providing an important degree of decision-making capability. This permits the computer to select a specific procedure from a range of alternatives so as to minimize delivery slippage. It may then assess cost penalties for specific types of disruptive events such as sequence changes, labor buildup and turbulence, rework, staging area limits, etc.

An important ingredient is the presence of decision rules. These allow the computer to consider problem situations which evolve in the course of the simulation, resolve them in some reasonable manner and provide suitable cost penalties. Important examples include: (1) allow for extra costs from loss of learning due to design changes and interruptions to scheduled operations; (2) initiate out-of-sequence work due to parts shortage or late design and reassign crews to high-priority operations, at extra cost; (3) provide extra handling due to crowded staging areas and select alternative methods to meet capacity shortages; and (4) increase manpower and overtime levels as schedule slips, inject extra cost for new people as crowding develops and reflect training costs of new personnel due to workforce expansion and turnover.

Exh. III-E

SIMPLIFIED NETWORK

For House Construction



Notes:
Numbers indicate days duration.
Red (heavy) arrows denote the critical path.
* - Omitted by HPE version. Time estimated by arch. designer.

As a simple example, a model was devised to describe a major steel fabrication activity - tanker hull construction. It clearly demonstrates the severe impact of variability from schedule in the start dates of hull modules, of interruptions to the regular flow of work, and of a modest increase in the cost of one major component due to design changes.

The model was built on fourteen characteristics of hull construction. The first eleven of these were used to run a benchmark simulation involving no variability of module start dates from their normal flowtime requirement, or of labor performance. Subsequently, the last three conditions were added to reflect the impact of design delays and changes. As a result, there was an expansion of 41 percent in the completion or "launch" date, and a cost increase of 22 percent. Since the design cost increase was eight percent, the net disruption cost was fourteen percent. No provision was made to minimize schedule slippage, which would introduce further cost penalties.

- Practical Labor Estimating -

Construction of a complete simulation model for major new program is a time-consuming task and requires much detailed data, even when restricted to labor hours. So, while such models should be constructed where cost and time permit, it is desirable to have a more economical approach to the prediction of disruption effects. For example, a simpler model can incorporate more traditional estimating procedures, applied with specific consideration of the effects of design delays and changes, while allowing rapid adaptation to a variety of conditions for use in "what-if" exercises.

An important objective is to determine the degree to which potential design delay, design changes and time compression force the production operation to deviate from its original plan (presumably that plan has been matched to the plant's capacity and operating procedures). Hence, the first step in the simulation is for the user to provide such data as the schedule of production deliveries, basic flowtimes, the initial cost level for each major department or task, and their labor input patterns, major precedence relationships between tasks (a simplified network), and the improvement slope to be followed.

The computer uses this data to develop and display a basic manhour plan for the project, which shows the progress and labor hours for the project as it would be without design uncertainty. After making necessary adjustments, the user proceeds to enter his forecast of design delays and changes, and their disruption effects. An interactive computer procedure provides appropriate guidance in entering a number of important judgments regarding the effects of design delays and changes on labor hours. This allows him to assess the reasonability of his entries in relation to each other and the end result, and to adjust them as necessary.

The model already offers promise as a practical tool for testing hypotheses as to the causes of known amounts of disruption cost, and for estimating potential disruption effects. As greater experience is gained, it will be expanded to provide for time-phased labor rates and costs of overhead and material.

IV. EVALUATING THE QUALITY OF MANAGEMENT

Up to now, we have mainly addressed the disruption produced by concurrency of design and production to meet a tight delivery date. Two other sources of major disruption - force majeure and inadequate planning and management - have not been covered in any detail.

The overwhelming nature of force majeure makes extensive discussion here inappropriate. The term itself denotes "an unexpected and disruptive event which may operate to excuse a party from a contract"*. Literal translation yields "superior force", which suggests the need to bow to factors or events of substantial power not under one's control. For example, natural disasters, war, strikes, etc. are essentially beyond rational prediction. Such events are subject only to limited protection, as by insurance, or to evaluation in terms of long range trends. It would not, for example, be prudent to expand one's investment in a country known to be headed for revolution, except under circumstances offering unusual protection and/or rewards.

The responsibilities of management in a disruption process, however, requires our close attention. The quality of management can affect the outcome of a development project in many ways. Equally important, the uncertainty of product development can severely limit the power of the managerial function, so that major concurrency of development and production virtually pre-empts good planning and administration.

1. Key Managerial Functions

Managers inevitably become steeped in the skills, the knowledge and the lore of the industry in which the enterprise functions. Many good managers are also experts on their industry, or in some special aspect of it. Nevertheless, that is not their basic function as such. It is indeed the manager's responsibility to ensure that he has the facts needed, and he must be able to decide whether he is actually getting them. This requires some degree of knowledge, else he would be unable to communicate his questions or absorbe what his advisors are saying. But once an "appropriate" level of technical background is obtained, his function is to exploit it by actions designed to advance the relevant interests of the organization.

Under one classic definition, the management process may be characterized by five functions: planning (obviously toward an objective), organizing, staffing, directing and controlling**. This description does not identify two characteristics crucial to this discussion. First, is the constraints imposed by time and physical resources (human, physical and financial). The manager must think in terms of developing a plan that is possible of attainment, which entails evaluating the resources and time available to be used. Organizing must similarly be concerned with the resources available in the form of staffing, and even with the capability available for directing and controlling. In short, resource and time limitations envelop the entire management process with a web of interacting relationships, which must be considered meticulously.

Further, in performing his tasks the manager must determine whether a situation contains hidden problems, and what their real sources may be, using the limited information which may be gained or analyzed in the time available to him. The critical importance of the manager's problem identification and analysis activity has been acutely described as follows***.

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Note: * Random House Dictionary, unabridged, 1973.

** See, for example, "Principles of Management" by Koontz and O'Donnell, McGraw-Hill. Also a modified version in "Management" by P. F. Drucker, Harper & Row 1974, pages 393 and 400-401.

*** "The Rational Manager", Kepner & Tregoe 1965, 2nd Edition 1976, p. 39. Privately printed.

"The raw material of management is information...about the world about him, about his organization and its plans, about the performance of that segment of the organization where he is responsible for carrying out those plans, about people and things and conditions...He must be as perceptive in recognizing, before the fact, what information will be relevant and important and what will not as he is in recognizing, with the benefit of hindsight, the obvious relevance and importance of certain information."

and again*:

"With management growing progressively more complex, and experience more obsolete more rapidly, the manager must rely more and more on skillful, rational questioning, and less and less on experience."

It is clear that management decision-making requires a considerable degree of abstraction (as opposed to withdrawal) from day-to-day events. Only in this way can the manager move into the realm of ideas in which logical analysis can lead to an effective decision, without which he cannot resist emotional involvement and the bias of his experience and associates. This is not to say that things necessarily must be analyzed mathematically or on a computer. The process is more like what happens when a scientist is groping for a "fruitful" hypothesis.

Drucker attacks the point from a somewhat different direction - that of making a decision - but the essence is similar#:

"A decision is a judgment. It is a choice between alternatives. It is rarely a choice between right and wrong. It is at best a choice between 'almost right' and 'probably wrong' - but much more often a choice between two courses of action neither of which is provably more nearly right than the other.

"...managers who make effective decisions know that one does not start with facts. One starts with opinions. These are, of course, nothing but untested hypotheses and, as such, worthless unless tested against reality. To determine what is a fact requires first a decision on the criteria of relevance, especially on the appropriate measurement. This is the hinge of the effective decision, and usually its most controversial aspect."

The natural tendency for managers to become set in their ways of decision making is especially dangerous in the presence of rapid change. At that time, old baselines are shifting and the accustomed categories of thought are becoming irrelevant, and new technical training and disciplines may be essential to function efficiently in the new environment. The need for abstract thinking is radically intensified. This suggests that the manager be trained in a variety of basic diciplines, to simplify his adaption to constantly changing technology. Paradoxically, he must be a generalist in basic information and knowledge in order to handle the extreme specialism of today's world.

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Notes: * Ibid, page 23.
Op. cit., pp. 470-471

2. The Impact of Uncertainty

It is commonly presumed that any major disaster (except force majeure) signifies poor management. But that fails to recognize that some degree of uncertainty is inherent in events. It also ignores the important degree to which managers operate under severe time and resource constraints, and must be selective regarding the information they seek and the degree to which they evaluate it prior to taking action. Thus even first-class management cannot be infallible, so that disastrous events may happen under its administration.

To use a sports analogy, when two football teams of top ranking meet in a bowl game, the losing coach is rarely accused of poor management. This is true even though mistakes were made on the field and the winner may have exploited the loser's weaknesses. It is recognized that the loser had to be superior to get into the game in the first place, and that it was almost inevitable that someone would lose. Again, in baseball a batting success ratio of only 30 percent is considered highly competent. Drucker applies the idea as follows*:

> "The focus of the organization must be on performance ... But performance does not mean 'success every time.' Performance is rather a 'batting average'... it must have room for mistakes and even for failures. What performance has no room for is complacency and low standards."

Some degree of uncertainty must always be faced. In planning future activities the manager obviously must minimize it; this is one reason for his chronic conservatism.

- Balancing Risk and Reward -

Now suppose the degree of uncertainty can be quantified, either by using past experience or by applying analytical techniques on the basis of a supportable theory. We must face the question of how to judge a manager's decision to proceed when he knows that there is significant probability of failure. To do so requires some sense of how such a risk is evaluated.

In accepting risk, the terms of trade must be clearly assessed, and these will differ from case. For example, economic growth is worth less to some managers (or to their capital sources) than to others. Thus, arriving at a rational balance of risk against reward requires an explicit idea of the relative value of specific losses and benefits. This makes the "utility function" a key item of the manager's tool kit - the idea that the financial consequences of a decision are not just proportionate to the dollars involved. For example, one investor may accept a twenty percent chance for a loss of a million dollars if there is a ten percent chance for a profit of five million dollars, while another will not dare. The terms of trade vary between people, and even for the same person it will vary over time.

Even within this set of value systems the risk of total failure must be minimized by suitable plans. An important means of limiting the chance of major damage caused by failures of individual tasks in a program is to establish practical alternatives or "backup" activities. The benefits of such redundancy may be expressed by a simple example. Suppose that three activities - A, B and C - must be completed successfully, and that they have individual success probabilities of P_A, P_B and P_C. Then the probability of success for the total project is $P = P_A \cdot P_B \cdot P_C$. For a value of .80 for each activity, this yields an overall success probability of $P = .8^3 = .512$.

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Note: * Op. cit. pp. 456-457.

Now suppose that each activity has associated with it an alternative activity. In other words, for activity A to fail, both A and its alternative A' must fail. Further assuming that alternatives A', B' and C' also have probabilities of .80, we may compute the revised probability of success as P' = .885. The improvement gains significance when we consider its converse, the probability of project failure. This drops from 1 - .512 = .488 to 1 - .885 = .115, a cut of over three-quarters. Thus, if the actual cost of the project were to be doubled by the redundancy, the probable cost of failure would be less than half.

Summing up, in view of the inherent uncertainty he must deal with, realistic judgment of the manager's competence must face five main questions: (a) whether the game was worth the candle - was the project's objective big enough to warrant the resources and risks involved; (b) whether the alternatives to this action were rationally defined and considered by all concerned; (c) whether the probable results of those alternatives were as undesirable as failure of the project under consideration; (d) whether suitable steps by which to prevent failure or to hold its cost to a minimum were available and (e) whether the manager provided adequate monitoring of events to detect deterioration of the situation at an early stage, and to limit the losses (this also requires planning those limiting steps in advance).

Clearly, we cannot fault a manager merely because he proceeds in the face of posssible failure; his decision can be entirely valid whether or not the consequences turn out to be favorable. Going into a dangerous situation with open eyes is quite different from going in merely knowing that it's dangerous. Were all the above questions properly addressed before proceeding, the losses due to an unfavorable turn of events would usually be limited sufficiently to avoid disaster. Equally important, if that disaster ultimately did occur, it should be relatively "acceptable" to the value structure of the manager and his sources of capital.

- Facing the Unmeasurable -

Unfortunately, the degree of uncertainty and the potential effects of unfavorable events are often frustratingly difficult to determine. Many situations involve potential events whose probability is not measurable. All too often the term "calculated risk" refers to a decision reached in recognition of factors known to be unfavorable but not susceptible to calculation. The future may even involve events of a totally unexpected or unknown type - sometimes termed "unknown-unknowns" or "unk-unks" for short. Thus, in dealing with complex problems under limited time and other resources, substantive errors in judgment can occur in unpredictable ways.

For example, there could be a shift in market structure subsequent to making a major commitment for facilities or advertising. Straws in the wind may even have been there, but they were simply not read because knowledgable people thought the time was past for further study and the hidden weakness compounds to become a debacle. It seems intemperate to describe such an error as poor management — there is just some irreducible degree to which things like that will happen.

Here, the prudent manager can only defend himself by establishing stringent monitoring of all areas in which a sudden shift in events might have such a substantial impact (avoid surprises), by establishing practical back-up alternatives in each area (systems redundancy) and by being alert to the need to limit damages

and even abort programs as appropriate (catastrophe planning). The policy of "minimax" (minimizing the maximum damage) is not a bad way of describing this.

- The Risks of Technological Change -

As used here, the term "technological change" refers to two conditions. One involves the development of new engineering knowledge; the second refers to the process of closing a major gap between an organization's area of expertise on the one hand, and what an undertaking requires it to perform on the other.

Technological change involves substantial uncertainty for the organizations affected and its links with management process are complex. There are many practical consequences for the decision-maker. For instance, a program involving concurrency of design and production is riskier when a small quantity of production units is involved. A larger quantity provides the opportunity for a greater sales income, through which disruption costs might be recovered.

Rapid technological change causes managerial uncertainty simply because prediction has so little to go on, Valid judgments are based on a blend of fact, experience and confirmed theories which do not apply fully to a substantially unknown technical situation. The effects are pervasive, ranging from the sudden ineffectiveness of familiar technical skills, experience and operational procedures to the impact of recondite scientific laws. Further, a real technical advance requires much knowledge and judgment from technicians, who are not always easy for the manager to understand or interpret. The manager operates with the uneasy feeling that there may be buried somewhere an assumption or prediction which, under more rigid scrutiny, may prove to be both critical and fallacious.

Under technological uncertainty many key judgments cannot be made in advance, and those made may prove wrong. The entire program cannot be fully planned , but must evolve. It is, then, not surprising that concurrency is costly for the production process. Great effort is required to establish production momentum, and it is costly to shut it off or slow it down and then re-accelerate. The production organization is poor at responding to the inherently sporadic character of a development program, and its floundering - like a fish out of water - is dreadfully expensive.

It might seem obvious that the solution is to avoid concurrency, or at least to limit it to areas in which redundant or alternative courses of action offer options by which to avoid major disruption. But the matter is not so simple.

For one thing, competent managers may be unable to differentiate between one case which contains the seeds of disaster and others which don't. This often happens in times of rapid technological change when the manager's relatively limited technical knowledge requires that he depend even more than usual on his advisors. Second, the costs generated by concurrency are not concretely measurable. Thus, they seem less real during the project planning phase, which intensifies the difficulty of evaluating the risk.

Third, a period of generally rapid technological change is usually one of intense competition, since a major advance by one enterprise can deprive others of substantial business. As a result, there is great pressure to minimize the time devoted to development of new concepts and hardware, so that significant development work overlaps with production. Fourth, an organization may be "forced" into concurrency to avoid an even worse situation. For example, older products

may be obsolete and dying on the vine, making new development of prime importance to maintaining minimal return to investors, or to avoid dismantling a specialized production and marketing organization which required much time and cost to develop.

Whether to permit concurrency is a crucial managerial judgement. If a proper decision is to be made, the issue must be defined clearly in terms of the degree of risk being taken and the potential benefits from taking it. This is not easy to do. Going to a more dynamic pace of product development will open up new markets for rapid expansion at attractive prices, generate important cost reductions due to new processes or designs and provide opportunities to develop talented technical and marketing organizations.

However, the risks are substantial and hard to assess: serious technical failures; heavy costs of design, production startup, field engineering and customer service; major capital investments in production and marketing facilities - often greater than predicted; possible large overruns of production cost targets due to design delays and changes; and new marketing methods and personnel may require more time to become effective than anticipated, while there may be downright errors in measuring the effective market. The manager must recognize that these risks exist, define them in detail, and measure their impact as best he can and provide for them in his comprehensive planning and contingency analysis.

3. Evaluating Management

- A Definition of Good Management -

In defining good management it is not sufficient to prescribe the five basic functions. There must also be suitable regard for resource constraints and uncertainties plus adequate technical skills and knowledge and competent judgment in relying on the information and in using the resources available. Good management should, for example, minimize the chances of a major debacle in any area, and its effect if it happens. It is, of course, best identified by a persistent record of success, but it will not always be successful, reflecting the uncertainties inherent in its environment. Then too, in evaluating a specific manager we must allow for individual differences in capability. Some men can make things happen that others cannot, while two managers each may have superior capabilities in areas that the other does not.

The "standard" for performance is then a broad baseline defined by the general practice and level of competence in a given industry, plus reasonable anticipation of the effects of outside events. Hence good management is exhibited by any manager of basic competence who attempts to recognize and work in a professional manner within the constraints of times, resources and personal capacities to meet his assigned objectives.

We may further specify this definition to say that adequate project management exists if it meets five conditions. First, the organization clearly has competence for the type of work undertaken (as-contracted). Second, it makes reasonable provision for differences between prior work and this project. Third, it has enough capacity to handle all its commitments (space, equipment, vendors, personnel and finances). Fourth, it plans realistically the detailed steps required to perform the task, identifies areas of risk, and provides appropriate back-up and bail-out options. Fifth, it assigns suitable capacity and key personnel to the task, and directs and controls their efforts in a reasonable way.

"Poor" management, then, results from the clearcut absence of one or more of the key characteristics of good management. A marketing disaster, for example, may reflect poor work in assessing consumer demand, reliance on inadequate salesmen, superficial planning or lack of follow-up. Some cost overruns occur through inadequate cost estimates, which themselves reflect poor planning.

- Performing the Evaluation -

The difficult task of evaluating management quality becomes more tractable if we divide management activity into three main categories.

First, is the vast number of "administrative" actions and decisions; they may require skill and experience but they can be performed fairly routinely by properly trained people. This includes handling the details of production operations or a marketing program, internal coordination of engineering, marketing and manufacturing, the establishment and operation of reasonable policies and procedures for production scheduling and accounting, etc. Such matters as organization structure, plant location, etc. are more difficult, but in general it is possible to arrive at rather clearcut judgments of managerial adequacy for administrative activities.

However, it much harder to evaluate decisions on major product selection, long-range strategies of various types, or the power of leadership to inspire a major effort toward challenging new goals. Such major decisions involve close judgments on which reasonable men may differ, largely due to the uncertainty inherent in the projections on which the decision is necessarily based. A third area involves major product development, which involves substantial uncertainty in the effectiveness of the efforts undertaken to achieve the objective or in the time required to do so.

It is often difficult to reach a clearcut judgment that poor management was responsible for a particular disaster. Inherent uncertainty could well account for some situations, while technological concurrency will account for many others. Thus, it may be easier to arrive at a judgment of <u>good</u> management than it is one of <u>poor</u> management.

V. AVOIDING DISASTER

It seems inevitable that organizations will undertake projects involving concurrent product development and production. When this occurs, it is essential to evaluate the risks and costs involved before commitments are made. It is equally important to manage it with reasonable assurance of meeting the original requirements for delivery, performance and cost. To do either requires an understanding of the concurrency phenomenon in general and how to manage it in a given case. Having covered the former topic in some detail above we shall now briefly address the latter, with special attention to minimizing the chances for a real disaster.

What might be termed "preventive medicine" involves four basic elements: pre-program analysis, periodic performance reviews, an effective early warning system and firm corrective action to limit the impact of unanticipated problems.

<u>Pre-program analysis</u> focuses on identifying the proposed program's degree of development concurrency and on forecasting its potential effects on cost and delivery. Such analysis is not easy to develop, but it may well lead to a sharp

expansion in the estimated cost and delivery time for a program and second thoughts on its relative desirability. The process requires, first, a careful assessment of the uncertainty involved in the development work contemplated, with due regard to the degree of advance in state of the art as compounded by interrelatedness in both design and production phases. This is not an easy task. Extensive technical counsel is useful, but the conclusions of technicians must be supplemented by the healthy scepticism of administrators who have seen carefully planned technical developments undergo spectacular failures.

A second major aspect of this review is to determine the degree of overlap or concurrency between the production and development phases. Again this may not be easy to do, since this judgment is also predicated on the degree of SOAA required and an estimate of the time required to accomplish it. However, by using conservative experience, allowing for contingencies and providing redundancy or backup in the most crucial activities, a reasonable assessment is usually possible. When this cannot be done the program requires severe reconsideration.

A third step is to measure the potential disruption of cost and delivery which may occur as a result of unfavorable events. This requires careful determination of should-cost as-built, which involves an assessment of the degree to which the initial configuration will undergo design changes, which naturally occur in a disorderly manner. The cost of disruption itself may then be addressed by developing some sort of model which explicitly considers the impact of design delays and erratic design changes on the total production system: engineering release, vendors, tooling, facilities, production labor, associated price levels and overhead costs and the effects on capital investment. This analysis must distinguish the fundamental cost of an undisrupted product from the effect of design delays and changes.

Completion of this estimate may well produce a marked revision in appraisal of the project, which leads to rejection and makes further analysis unnecessary. If not, we must then evaluate several managerial aspects. Is the planning in sufficient detail to expose all crucial decisions and to define the critical areas for monitoring and control? Are the plans consistent with organization capacities as they exist or can they be reasonably supplemented at appropriate future times making explicit allowance for the demands of unpredictable variation from the expected course of events? Have the characteristics of necessary controls been clearly defined and is the organization capable of implementing them - not in terms of paperwork procedures, but as concrete measures of organization, observation, reporting and decision?

Once the program has begun, periodic review of performance will proceed in a similar manner to the initial analysis, with the obvious simplification permitted by completion of the original evaluation. When no such evaluation has been accomplished, a similar comprehensive checklist must be employed in the performance review. In any event, the latter will concern itself urgently with identifying areas in which the development process is generating potentially serious disruption not explicitly anticipated earlier. Given such events, the next priority will be to evaluate their impact and how they must affect the ultimate value of the program.

Once committed, it is difficult for an organization to be objective about such matters, and one function of the operating audit is to force cold-blooded evaluation of the consequences which may be evolving. There is rarely a clear-cut answer to such situations; no program can be expected to be without problems and faint-hearted men rarely accomplish large things.

Further, important outside circumstances may differ from when the program was initiated, so as to change the relative impact of the new problems. There are few definite rules for such an evaluation.

The development of an early warning system for a program involving substantial uncertainty requires establishing suitable measures of performance discrepancies to warn of an emerging program. This relies heavily on judgments of where the uncertainty is most likely to develop. The enormous implications of such problems make it essential that these warnings be promptly transmitted to the highest levels and that they be carefully appraised rather than treated as merely another statistical report. Continued use of the disruption model previously developed also may help in detecting significant difficulties.

Lastly is the matter of corrective action once a significant problem has developed. Should it fall within the range of the original estimates, the appropriate response should have already been determined - at the least, the risk will have been considered and the cost found acceptable. Perhaps, however, external circumstances have changed sufficiently as to require further review of the situation. Should this be, or should the problem appear to exceed the original range of expectations, urgent consideration by top management is called for. The necessary action may be draconian, including substantial infusion of new technical or managerial resources, termination of the project, a merger or other sharing of risk, or even bankruptcy of the company. The important point is that consideration of such drastic steps must come much more quickly than for less risky endeavors.

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DEPARTMENT OF DEFENSE
THE MANAGEMENT OF MAJOR SYSTEM ACQUISITION

Robert E. Berry
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Mr. Berry was kept from the meeting by pressing last minute business and his paper was delivered by Mr. George W. Sutherland, Assistant Director Systems Acquisition Management, Director of Defense Research and Engineering.

The management of major system acquisitions in the Department of Defense has been a principal topic for public discussion since the early sixties. I would characterize the general mood of the discussions to be an expression of concern--an expression of dissatisfaction in the results achieved in the conduct of individual programs. We could list a number of programs that have been scrutinized thoroughly in full public view and the measure of management achievement rated marginal to unsatisfactory.

Within this environment there is a natural urge to counter much of the criticism by describing the massive task of management together with the complexities of risk and uncertainty; concluding with the judgement that the results have been acceptable and those who are not in the "pan" are not qualified to be critics. Certainly there are many who share this view, and defend their conclusions objectively and sincerely. There is no question the task of managing major system programs is complex, uncertain and tough--those who have the job are not unreasonable in their own defense. Equally reasonable, however, is the public view of the management process when measured by the ultimate results compared to initial estimates and goals.

The management process involves an interaction between people who are generally directed toward common goals and objectives. While the results achieved are visible to many, the internal management process and mechanisms are visible to few--excluding most if not all those on the outside looking on and many of those within the operating group who are directly involved and contributing to the results. The output characteristics of the management process are not physical and lack the material shape of the normal product. I believe we fail to give proper substance to management as a discipline or function in part due to this lack of material quality.

There is a popular presumption concerning management that places the focus on output--on the results and as they say in the business world, the bottom line. Whatever the result, management is accepted to be the cause. In the view of those who look to the Department of Defense for results, this presumption is reasonable; however, the matter of improving results through improvement of the management process demands, more than a focus on results. In correcting the problem, we must deal with the entire span of the management process starting with input and progressing through to output. The attention directed to the formal process of interactions and decisionmaking must be thorough from top down. We must learn to deal with management as a physical task and understand the product in material terms. We cannot ignore the individual interactions and pass them off as part of an informal process of the organization. We must recognize that fixing management problems is a physical process as much as bending metal--we are shaping people things, we are establishing tangible control techniques and procedures to cause the evolution of a product down the line from input through output.

As you know, the management of major system acquisitions in the DOD is undergoing change. These are important as well as complex changes that must have support and understanding throughout a broad segment of Government, industry and academic institutions. These changes are not the result of an isolated DOD undertaking. The base for these changes is Government-wide; we are no longer addressing an area of management activity that retains the image of being part of the Defense domain. Today we share the stage with many others--I believe this is good since we now have a broader base for judgments as to what is best in the form of policy and in the form of standards to measure satisfactory results. As the only fish in the bowl there is the danger of isolated viewpoint and parochial behavior as well as the lack of an adequate base on which to assess the quality of performance.

There has been good progress in moving towards an improved major system acquistion process. This progress has not come through the efforts of DOD acting in isolation. I believe we are beginning to see the value of the broad-based effort to make meaningful change in the management of major systems throughout Government and industry. The purpose of this paper is to address this process of change in the DOD in the proper perspective and to point out that the direction of this change is not based on the judgment of a single agency but the collective effect of many independent viewpoints. It is also clear that Defense would not have made many of these changes without the sustained influence of outside activities in the past several years.

Change should not be taken lightly. Nor should we assume that change is necessarily for the better. Those involved in the process of change must listen well and insist on caution and logic as the action progresses. I would be quick to add--we are not dealing in the short-term; the task to be accomplished demands knowledge, patience, determination and time. The tendency to status quo is instinctive to most people at all levels in an organization. As I stated earlier we must view management as a physical thing producing a material product. Within Defense we are changing basic structure when we tamper with the management process and should not expect instant agreement.

This is not to say that disagreement or resistance to change is bad. Quite the contrary, intelligent resistance to change is healthy since we are moving from a known set of conditions to the unknown. There is security in dealing with a known process, even though there are accepted shortfalls. Those who strive for change with the vision and conviction that improvements are essential and feasible must accept the fact that the road is all uphill and each facet of change must be presented with the logic required for acceptance.

Major system acquisition is a management technique that is product focused. We structure a program around a major product to be managed by one manager and include within the program structure all of the elements essential to the employment of the product throughout its life cycle. In this manner the product and the related elements are integrated to form a system. The system management concept is not a new technique--the process has evolved over the past some 25-30 years in the Defense Department and in segments of industry as the complexity and cost of weapons has increased. The program management techniques have been developed over the years through application to aerospace, sea and land systems. Throughout the evolution of the system acquisition process, the period of the sixties appears in history as a major milestone in shaping the direction we are now moving. We might say this was the time when the management of major system acquisitions went public. There was an increased awareness of the problems encountered in the management of major systems. The Congress became increasingly involved in the technical, cost and schedule specifics of individual programs. The media discovered new fields of public interest and provided extensive coverage of problems encountered as major programs progressed in development.

The increased concern in the management of major programs produced extensive public debate--not always presenting the basic management issues accurately. Perceptions of problems were not always founded on knowledge of the inner-workings of the management process. There was, however, agreement that the problems as manifested in the results achieved in various programs required strong, positive action to improve the management process.

From the vantage point of hindsight, we might agree, with some debate, that the single most important action in establishing a foundation for improving the major system acquisition process was taken by the Congress in legislation to create the Commission on Government Procurement. I believe this action taken by the Congress and the work of the Commission to be a benchmark of substance and we must not allow the values of these events to be overlooked or to recede into dusty shelves as so many have in the past.

In this regard, I refer to a highly appropriate observation made in testimony given by Mr. Gilbert W. Fitzhugh, Chairman of the President's Blue Ribbon Defense Panel before the Senate Armed Services Committee, December 1971. Mr. Fitzhugh noted that when studies are completed and committee members depart, those who remain behind to assess and implement recommendations are those whose toes have been stepped on in the findings--there is a noticeable lack of support. A study report needs an advocate to remain behind to give support to the findings with understanding and conviction when the members complete their work.

I believe Mr. Fitzhugh's comments are valid--in the process of change, there must be advocacy. The Report of the Commission on Government Procurement is meaningful and has major value in guiding the direction of change. The value of the Report is not in the sense that we must subscribe to all of the expressed viewpoints and recommendations, but to recognize that the Commission completed a study that is current and relevant and qualifies as the most comprehensive and best focus on the subject of major system acquisition. The Report should serve as an effective foundation for change and we should continue to support the goals and objectives set forth by the Commission notwithstanding the views we may wish to debate on individual issues.

OMB Circular A-109, "Major System Acquisitions," issued 5 April 1976, effectively translates the findings of the Commission, dealing with major systems, into Federal policy. The Department of Defense looks to A-109 as a major statement of policy and has directed its attention to implementation. In the implementation of the A-109 policy, there must be a clear understanding of issues; an appreciation for the complexity of the process and recognition that there are no simplistic solutions. The actions directed to management improvement must be conducted with knowledge and persistance; anything short of this will not succeed.

Subsequent to the Report of the Commission on Government Procurement there have been several related DOD studies directed to specific areas dealing with the management of major systems; the Army Materiel Acquisition Review Committee (AMARC), 1973-1974; the Navy and Marine Acquisition Review Committee (NMARC), 1975; various Air Force studies; and the Acquisition Advisory Group(AAG) in 1975. Individually and collectively, the Commission's Report and the internal DOD studies provide a valuable body of information directed to the improvement of system management. The actions being taken by Defense rest on this foundation.

Action by DOD to proceed with the implementation of changes to the major system acquisition process was initiated formally in early 1976. Direction was given to the Director of Defense Research and Engineering to implement selected recommendations submitted by the Acquisition Advisory Group. While the initial action was taken in response to the AAG report is important to understand that the overall planning for change and the actions

taken were based on the OMB Circular which was in process of issue and subsequently was issued in April 1976. While the AAG Report was directed to a specific and limited segment of the process, the recommendations support important areas of policy in A-109.

Changes planned and underway in DOD involve specific areas of the major system acquisition process. It is important to recognize we are dealing with change to a well established, existing process that does not bend or adjust with ease. The task is not to revolutionize the process; the task is to make specific adjustments and bring the management process into alignment with the new policy. The areas of change are well defined and the work of restructuring the process underway.

The principal areas of change in terms of the impact of the new policies on the DOD process involve the following:

1. Creating the role of the Defense Acquisition Executive to provide for the integration and unification of actions in the management of major system acquisition.

2. Restructuring the front-end of the major system acquisition process to establish a new Secretary of Defense decision point based on mission need.

3. Decentralization of selected program review actions to the Service Secretaries in support of the Secretary of Defense decisionmaking process.

4. Establishing a management methodology for the development of a planned acquisition strategy tailored to individual programs.

In discussing these key issues, it is not the purpose here to justify the change but rather to present the changes as implemented in the Department of Defense and the goals and objectives of the new policy.

Defense Acquisition Executive

The basic responsibility of the acquisition executive as set forth in A-109 policy is to integrate and unify the system acquisition process and to monitor policy implementation. Certainly, this function is a major role of the acquisition executive is expanded to a larger role than envisioned in A-109; the Defense Acquisition Executive, in addition to the responsibilities included in A-109, is the principal advisor and staff assistant to the Secretary of Defense in matters pertaining to system acquisitions. The importance of this position is seen in the supporting functions performed by the Acquisition Executive in the decisionmaking process--he provides a central role in the Office of the Secretary of Defense (OSD) to focus the several system program elements in the context of a total program and attempts to bring the best balance in developing recommendations for the Secretary of Defense. As Chairman of the Defense System Acquisition Review Council (DSARC), he has formal access to the corporate thinking of the Secretarial Staff, and is able to pursue separate functional viewpoints to the depth necessary in establishing the best total program action. In this manner, he performs a role similar to that of the Deputy Secretary of Defense in the previous organization arrangement.

The cross-function perspective inherent to the role of the Defense Acquisition Executive has been a missing role in OSD below the level of the Deputy Secretary. The OSD staff organization, typical of many large corporations, provides the essential functional expertese in the vertical staff elements but lacks the strong, central mechanism to present a management viewpoint that cuts horizontally across the staff in presenting the best solution. Typical of staff actions, cross-staff positions develop through the process of coordination and invariably, through compromise of strong staff positions to achieve a

common ground for agreement. In the face of two opposing positions, the compromise is acceptable but not necessarily the best total program action.

The Defense Acquisition Executive should provide the ability to improve the decisionmaking process in support of major system acquisitions by forcing functional staffs to assess their separate positions in the context of the total program. Trade-offs within and between elements should develop as more balanced program actions rather than one-sided functional actions. Good system program decisions require thoughtful compromise between staff elements in the real sense of the corporate interest to achieve the best program results.

Restructuring of Front-End

The single most important change to the DOD major system acquisition process to result from the A-109 policy involves the restructuring of the front-end of the process--those activities that occur prior to the full-scale engineering development decision, starting with the request to initiate a new major system acquisition program and progressing through to the identification of a system proposed for full-scale development. In this phase of the system acquisition cycle, occur the most fundamental decisions and actions in shaping the program to acquire a solution to meet a Defense mission need. It is in this phase where we have the greatest opportunity for error in creating the basic conditions for a successful or unsuccessful program as ultimately judged by the results achieved.

Some will argue this view to be an overstatement of the impact of early program actions on the final results. I do not believe so. There is much evidence to show that the impact of the early program actions is vital in determining the quality of the solution selected to meet the mission need; the technical, financial, contractual, logistical and production characteristics of the program; and the degree of risk and uncertainty introduced in the decisionmaking.

In implementing the new front-end policy, the Department of Defense has established a new decision point identified as Milestone 0, the Secretary of Defense decision to initiate a major system acquisition program. This first action by the Secretary to consider the procurement of a new capability is directed primarily to determining the essential nature of the stated mission need and the reconciliation of the need to existing Defense capabilities, priorities and resources.

The initiatives to be taken leading to the Milestone 0 decision rest with the Heads of the Components and in the case of the three Military Departments, with the Service Secretaries. The DOD policy requires that the Services establish procedures for the continuing analysis of Defense mission areas to identify mission needs under certain conditions, however, the Secretary of Defense will also request the Service to take an initiative to pursue a solution to a mission need. Needs will be described in relation to segments of a mission area and identified as mission elements corresponding to the perceived need for a new capability. A mission element is not a preconceived segment but exists only as the definition of an identified need. The scope of the element is determined by the Service to be however broad or narrow as the Service may define the mission job to be done. The principal issue is that the mission element must describe the job to done in terms of the enemy situation and not in terms of a system to accomplish the job. The discussion of a mission need separate and apart from the system to perform the task is new to the DOD and is not an inherent ability of the existing functional activities in the Services or OSD. There is considerable learning involved in the full implementation of this concept and we would not limit our view of the change in terms of existing organizational functions since it may be necessary to introduce new functional groups and techniques.

At the time that a mission need is identified and a determination made by the Service that a new capability is required to meet the need, the Service will prepare a Mission Element Need Statement (MENS); a key document introduced by DOD to communicate mission needs to the Secretary of Defense and requesting approval of the need and the initiation of a major system program, simply and without delay. The MENS serves the same purpose in the Milestone 0 decisionmaking process as the Decision Coordinating Paper (DCP) serves in the subsequent decision events, Milestones I, II and III. Defense System Acquisition Review Council action will not be involved at Milestone 0.

The MENS thoroughly documents the details pertaining to the mission element need, the existing capability to accomplish the need, the basis for the stated need for a new capability, program constraints to apply to all potential solutions, the impact of not acquiring a new capability, and a program plan to pursue the program through to the point of the next Milestone decision.

The content of the MENS has been limited to information essential to the initial decision with the principal focus on mission need, to include:

- the enemy situation presented in finite terms,
- the time period of the need during which the capability will be employed,
- types of targets to be attacked and associated tactics employed by the enemy forces,
- the threat situation to include identification of enemy systems, and tactics creating the hostile environment in which the system will operate to accomplish the mission need,
- reference to intelligence sources used in preparation of the mission data, and so on.

The sections of the MENS must communicate the entire perception of the mission need as the basis for the Secretary of Defense decision and subsequently as the basis for stating the mission need in soliciting competitive, innovative alternatives as potential solutions.

A second area in the MENS documentation that will require a change in approach is that of establishing program constraints. In addressing the problem of soliciting alternative design concepts on the basis of a statement of mission need, the response from industry cannot be open-ended in relationship to investment, manpower demands, operational and logistical considerations, possible treaty implications, the involvement of allied forces, etc. Often, program constraints are established as the result of a problem situation encountered in the development cycle rather than before the fact assessments. It is intended to place essential constraints in full force at the start. This requirement to state the constraints at the onset applicable to all solutions is an important part of the MENS and will require adjustments to the actions of functional people involved in planning system acquisitions.

The matter of limiting dollar resources committed to solving a specific mission need requires new planning techniques. Our treatment of funding needs in the past have been to budget for costs prepared as direct estimates of a proposed system well before the system has been adequately defined. Experience shows clearly that risk and uncertainty ultimately cause havoc with such early cost projections and have contributed to much of the criticism of management as discussed earlier.

The intent of stating constraints on the investment to be made by Defense in procuring a new capability is to place a value on the mission need in terms of the maximum investment the Department is willing to commit from future budgets. The statement of funding constraints is not to be based on the cost estimate of a projected system and more importantly is not to be accepted as an estimate. The DOD works with 5, 10 and 15 year projections in a formalized planning process. A portion of future budgets is always committed to ongoing requirements and the open budget available to meet new needs is not unlimited. Within this constrained budget structure the commitments to future expenditures for new

system capabilities must also be constrained.

The documentation of budget constraints in the MENS is to apply to all potential solutions not as estimates but as investment ceilings. Such a concept is well matched to the concept of design-to-cost and on a broader basis, design-to-life-cycle-cost.

We may argue the concept of investment constraints in many areas to attempt to show the existing planning and programming system does not now function on these terms of reference. No question many of the arguments are valid today, but we are addressing changes that are an integral part of the restructing of the front-end of the system acquisition process. We must accept that when facing the requirement to establish future budgets well before there is definitive information on specific items to be acquired, there is no basis to proceed to estimate the cost of the items. Value judgments in terms of investment limits must be made in the context of the total budget and on the basis of established strategies and priorities. The Services must develop techniques to make these judgments within the framework of the force planning guidance issued by the Secretary of Defense.

The completed MENS forms the basis for action taken by the Secretary of Defense to initiate a major system acquisition program. If the need identified by the Service Secretary is approved the Secretary of Defense will direct one or more of the Services to proceed to identify alternative design concepts to meet the need.

The first phase of the system program cycle places emphasis on competition for innovative concepts across a broad technology base. The objective is to explore alternative solutions responsive to the mission need--not to establish system design requirements. Short-term contracts to evolve various concepts that show continued potential should be used. When the Service Secretary is prepared to recommend one or more preferred alternatives for further development through the demonstration and validation of design concepts, the DCP is submitted to the Secretary of Defense requesting approval to proceed with the next phase of the process. This next decision event is identified as Milestone I, Demonstration and Validation.

Following the Milestone I Secretary of Defense decision, the major system acquisition process proceeds with little change in format from the past, progressing through the demonstration of full-scale prototype systems and subsystems to the Milestone II Full-Scale Engineering Development decision, and subsequently to the Milestone III, Production and Deployment decision point.

A change has been introduced at the Milestone II event to include authority to procure long-lead production items and a limited production quantity of items to support operational test and evaluation. Secretarial approval of long-lead and limited production items at Milestone II will authorize the program manager to proceed with the limited production system prior to a decision to commit to full production at Milestone III.

Acquisition Strategy

A-109 policy requires that the program manager develop an acquisition strategy for conduct of the program as a key task following program initiation. Some may suggest that Department of Defense has pursued system programs under well developed strategies in the past. This view would be debated by most with valid arguments to show the strategies lacking in many areas.

The preparation of an acquisition strategy does not evolve down to an exercise in documenting the program plan. There is an intent expressed by this policy that requires the program manager to personally lead in the development of a strategy to be followed in

the execution of the program. The development of an acquisition strategy is intended to be a thorough assessment involving the technical, business and management activities to evolve an integrated strategy setting forth the approach for achieving program goals and objectives. The dominant characteristic of this action must be a strong business viewpoint and judgment setting the foundation for program execution. The strategy must answer the questions:

- how the Government will deal with individual firms from the first solicitations;
- how risk and uncertainty will be managed contractually;
- how the costs of risk will be shared by the Government and the contractors;
- what capital investment should a contractor be expected to make;
- what approach is to be taken on incentives and how can incentives be made effective in achieving the desired results;
- how the acquistion strategy will be implemented by contract actions;
- what type contracts; and so on.

The leadership of the program manager with the participation of all program functions is essential--action that results in the isolation of any of the functional groups will not succeed in the development of an effective strategy.

There is a need for the senior staffs in OSD and in the DOD Components to develop the concept through necessary policy and procedural techniques. Implementation must take place, however, at the program management level. The procurement community has done some initial thinking in this area, but there is need for much greater initiatives to be taken on a broader base and involving the other functional areas. In proceeding with the development of policy and procedures to deal with the matter of acquisition strategies, there is need for extreme caution not to use this concept to explode into a new paper dynasty--that is not the intent nor will-documents achieve the the purpose.

Decentralization

The issue of centralization versus decentralization has been discussed extensively with strong arguments for more of both. Without attempting to decide the issue in favor of one or the other, it is clear that the size of the OSD staff presents some limit to reasonable involvement of the staff in the details of individual system acquisition programs. There are some 80 major DOD system programs in process with a projected investment of more than $200 billion at completion. Each of these major programs are required to be reviewed by the Defense System Acquisition Review Council at each of the Milestones I, II and III decision points creating a substantial load on the staff. On the recommendations of the Acquisition Advisory Group, policy changes have been introduced in the program review process to delegate selected program reviews to the Service Secretaries at Milestone I. Programs that are generally within the scope of responsibility of a single Service will be reviewed by the Service Secretary and recommendations made to the Secretary of Defense. It is emphasized that this review procedure does not change the decisionmaking responsibility of the Secretary of Defense.

The Service, System Acquisition Review Council, the (S)SARC, has been established to conduct the Service review. The (S)SARC includes the Service Secretary's principal advisors similar in composition to the DSARC. The (S)SARC will conduct program reviews under the same policies that apply to the DSARC including the use of the DCP and submit recommendations to the Service Secretary who will in turn make his recommendations to the Secretary of Defense.

Viewpoints regarding decentralization continue to be split. The action taken to delegate certain program reviews is a key step but not a large step. There is a basis, however, for Service initiatives to demonstrate the values of such a move. The ultimate direction as to how much decentralization will depend on the effectiveness of the Services to conduct tough reviews with adversaries to challenge the program advocates.

These principal changes to the DOD management process for major system acquisition are extensive and the adjustments to be made throughout the broad areas of the functional and operating elements will not fall into place without an effort. To make changes in deep-seated operating methods in any large organization is a difficult task and the DOD should expect this task to be difficult. The basic policy changes have been made. DOD Directives 5000.1, "Major System Acquisitions," and5000.2, "Major System Acquisition Process," were issued 18 January 1977. The two policy Directives implemented the provisions of A-109 and were effective immediately within the DOD. All related DOD policies and procedures were directed to be changed to comply with the new Directives.

Action by the DOD Components to issue internal policies to implement the changes were to be completed in May 1977; however, some delays in meeting this schedule have been encountered. The actions by the Components should be completed without excessive delays. Notwithstanding these delays, the new policies are in effect and will be followed in the initiation of new system programs. This is not to say that there is instant change in the process--instant change has not been planned nor expected.

The new policies will not be back-fitted to on-going programs. Programs that have progressed to various stages in the system acquisition cycle will not back track over the completed actions to make adjustments required by the new policy. A program, for example, that has progressed beyond DSARC I, (the previous reference to Milestone I) will not be required to comply with the new policy covering the p--se activity back to Milestone 0. The new policy does, however, apply to all subsequent program actions.

The transition to the new procedures will be awkward for some initial period in dealing with programs at various points in the process. Certain programs projected by the Services as new starts in fiscal year 1978 are not in fact new starts under the new policy since these programs have progressed well into the concept phase under the prior policy. The Navy's VSTOL Type A system is an example of this point. The program was prepared for DSARC I at the time the new policy became effective. In restructuring the program for Milestone 0, numerous problems were encountered since the program had progressed to the selection of a solution concept with Secretary of Defense approval. Generally, programs approaching DSARC I under previous policies have been underway for periods varying from months to years. As such the application of the new policy must be accomplished on an individual program basis.

A strong argument has been made by some alleging that the new front-end policy will result in extending the system acquisition process. This argument has certain appeal on the surface, but has no substance in the light of more detailed debate.

Concern that the new policy for initiation of major system acquisition programs will extend the process is based on the addition of the new milestone decision point, Milestone 0. The position is taken, that the formal process will be extended a number of months and possibly as much as several years as a result of the requirement to submit a MENS for the Milestone 0 decision. In alleging that the system acquisition cycle is extended, the comparison has been made with the existing DOD process, starting with DSARC I as the point of program in initiation. It is true that in this comparison of the two procedures, the new process including Milestone 0 as the point of program initiation shows the formal process to be extended an additional phase. This comparison is not valid, however, since there is no recognition given to the conceptual work that is completed prior to DSARC I under previous policy. Past experience shows the conceptual activity to be prolonged over several years--the B-1 program is an example where the conceptual phase extended over a number of years prior to the DSARC I.

Contrary to the allegations, a strong argument can be made to show that the new policy starting with Milestone 0 may well result in a reduction of the system cycle. With approval of a mission need by the Secretary of Defense, there is reason to believe a program will move with more focus and with less delay simply due to the support that comes with approval at the top and the agreement on need.

The major system acquisition process is undergoing important changes. What can be expected to result from this change. Certainly this is not the first attempt at major change since in the past 20 years or so there have been other pressures to change the process. As I have stated, this particular change can only be effective in the long-term. The process cannot be expected to adjust quickly and there must be strong and sustained advocacy if these changes are to succeed.

Conceptually, the new policy has logic in dealing with the management demands of the major system acquisition process. However, in the long-term much can happen to policy actions with the tendency to revert to status quo. It is certain that the A-109 policy will not be implemented without a strong advocacy structure. Initially, this advocacy came from sources external to DOD. An advocacy base is urgently needed within DOD to sustain the change underway. This advocacy will not come through arbitrary commitment, but only through reasoned understanding of the policy and a conviction the changes will improve the management of major system acquisitions at all levels. The procurement community through the research program can participate in creating a base for support by carefully selecting research projects in key areas of change.

THE GAPS BETWEEN ACQUISITION RESEARCH, POLICY, AND IMPLEMENTATION

Fred Dietrich
Office of Federal Procurement Policy

I would like to talk a little bit about some of the difficulties involved in transitioning from research to policy to implementation in the area of Federal Acquisition. Believe it or not, these areas are inter-related and it is part of my job to see that they function interdependently.

Research is basically the development of a base, a past, present and advanced acquisition technology. The product is a body of knowledge about major system acquisitions. Policy is a broad conceptional criteria, not detailed procedures. It is not what we knew as the Air Force 375 series of procedures, which was a policy. Practice is the implementation of policy at the operating level. Not let's try to interrelate these. In general I look at it as a triangular situation with the three apexes of the triangle entitled Policy, Research and Body of Knowledge and Practice. I put the policy on top of that triangle. Of course Frank Hardem over here put Practice on the top and Policy and Research on the bottom and Ted Helmer from the Air Force Academy certainly put Research on the top and Practice and Policy on the bottom. But I've got the chalk and I've got the podium so Policy is on the top of the apex.

Ideally, we would have a free flow, with push and pull in each direction of the three legs of that triangle. What do I mean by the push and pull? Take the push between research and policy. The push from independent research is pushing policy development. You can understand how that might happen, and I'll elaborate. It's like the wet noodle. The pull is where the policy makers are asking for research results. The push from the policy down to the researchers is where the policy makers sponsor research, which is the ideal situation for the researchers. And the pull from research is where they independently initiate research based on policy. This push and pull relationship exists in each one of these triangles, or legs of the triangle. Now we'll try to develop them.

Let's examine the real world and some of its problems, at least as I perceive them. I'll state right now that I don't have pat solutions, but I feel that if we sort out, understand and discuss the problems, solutions are possibly less difficult. The real world we live in consists of our own separate worlds. An example is the "policy world." One can draw a gate or a fence around it. You can also draw a fence around the world of research or draw a fence around the world of the practitioners. We talk to ourselves within these worlds. It's much easier for me to communicate with someone who understands me so I talk to other "policy people." We have a tendency to tell ourselves in our own little world how great we are and complain about the other worlds. You know, they don't understand, they don't care about all these important things that I'm doing, or they're not trying to understand my problems. In fact, they're not even listening. The result is inevitable: we build fences. You know, my job is policy, yours is research. For example, from a researcher here is the typical thing that we might find: "Here's my research paper with specific recommendation for reforming the acquisition process. Please send me a copy of the policy which implements my recommendations. By the way, I've sent copies of my recommendation, which will save billions, to the President, the Government Operations Committee, the Congress, the GAO and Common Cause."

Now, doesn't that sound ridiculous? I'll admit I did expand a little bit on the distribution but it's basically true. That's real push. And the point is that before we even demand or complain about another, we really should, as the Indians say, walk a mile in his moccassins. We should recognize that each world has its frustrations, inhibitors, and constraints, and that the gates swing both ways in those fences. Ideally, the three worlds should work together in removing the fences to better understand the universe in which they are living. You may have to push one or pull it.

I'd like to turn to some parallelisms that may be helpful in understanding the points that I'm trying to make here. The first is from the Sloan School Study of Industries Comparative Investments in a push versus pull situation in systems acquisition. The push is an industry solution looking for a need. I know you understand that type of thing. That's like AWACS. A pull is the industry response to a government need. That's like when all the requirements are established, understood, and documented and then industry responds to the need. The study concludes that a push requires over three times the investment on the part of a contractor in comparison to a pull. This is about half way through the acquisition process, which is about four and one half years. In other words, selling the need as well as the product is much more expensive than responding with a product to an approved need. This says the wet noodle analogy is real. The moral of the story is, don't expect independent research products to be as readily accepted as those that are requested.

A considerable investment in marketing is required to have independent research results accepted. Demanding just builds the fences higher. For an example of effective marketing, we can go back and take a look at the work that was done at the Air Force Academy by Otto Martinson on Pie Cost. Otto perceived the need, researched the concept, nurtured it, and effectively marketed it by selling it, by demonstrating it, by testing it, and by assisting those who operated under it. Now Pie Cost has lost its title and Otto has moved on to owning a green Cadillac, but the product is alive and well in the government.

Now let's turn to OFPP as a policy outfit, and A109 in particular. Again the triangle. The Commission on Government Procurement, in their two year study, pulled the current experience, researched the past and developed twelve recommendations in Major Systems Acquisition. These were then pushed by the Congress through the Commission on Government Procurement Report. The Executive Branch then established positions on all twelve of those recommendations. The Office of Federal Procurement Policy, as a regulatory group, pulled the research and drafted a policy. That's where I came in the drafting of the policy. In the process of developing a policy, we exercised a pull on the current practices by coordinating with all the 96 agencies in the Federal Government, industrial associations (about 30 of them), industry, the GAO and the Congress. Congress had a part in A109. In fact, one of our great antagonists in the Congress, the House Armed Services Committee, had a significant input. We changed OFPP 1 to give greater cognizance to the laboratory participation in the major system acquisition progress. The push toward the practitioners began on April 5, 1976 and that was the beginning of the marketing effort which is about 80% of my job. The other 20% is creating.

What have we encountered enroute to this attempt to market? We've seen layers of policy with some skewing and increasing proceduralization. As an example, I'll take the top document, and I'll use the Defense Department since most of you are from there. The OMB circular, we think is fairly clearly stated, even for people within the Defense Department. We tried to write it so it was not "Pentagonese", but we've been accused of that before. If someone doesn't understand terms like "life cycle cost" or "cost of ownership," they call it "Pentagonese." We're finding out that some of the other agencies are waking up to the fact that what they call Pentagonese is real world terminology. OMB circular is reflected in some documents in the Defense Department. For example, there are 5001, 5002,

OSD level documents. In the Navy there are OFNAV Instructions, NAVMAT instructions, NAVSEA, NAVAIR, etc, etc, instructions. In the Air Force we have the OMB circular, OSD and then they respond with the Headquarters Air Force Reg. and AFSC and SAMPSO on down the line, ASD and so on. In addition to this layering, we find fragmentation of A109. A109, if you recall, is signed by two people; High Wit and Jim Lynne. The reason it was signed by two of them is because one had the authority that the other one didn't and vice versa. Wit had the procurement regulatory authority which in fact is reflected in A109 and Lynne had the authority to tell the agencies how to deal with Congress, how to submit budget information and how to manage. That was in his charter. It was not in Hugh Wit's. So as a result we combined all these things into one directive. However, when it comes over to the Defense Department we find that they are going to make it 5001, 5002, 5003, 5004, 5030, number 34 and 4105, 62 plus others and the ASPR is to be changed to implement the policy. Now, until we get to the practitioners in the field, what happens? What do we find when we get out and talk to a practitioner? The main thrust is lost. There are conflicting instructions, multiple interpretations, and they never heard of A109 or the reforms it requires. Government people are frustrated by these situations, especially when they face a contractor on the other side who has received A109 directly; read it, put on internal briefings, and understands it. The Contractor then gets frustrated on the other side of the table and wonders if the Government is ever going to change.

Thus, there is necessity for some orientation and training, at all levels. I'll ask in here, how many are interested in the work that they do? May I have a show of hands? Yeh, great. Now, how many have read A109? That's a good percentage. I think I sand-bagged you. How many have read OFPP circular, pamphlet no. 1 which talks about the application of A109? We went on a thirteen city tour and grabbed some people from the Defense Department, Bob Berry, and Al Espisito. We had NASA and ERDA representatives and representatives from industry who had some experience with A109 and held conferences in thirteen cities. We got a lot of feedback from those conferences and learned some interesting things, which I'll cover in a bit. The representatives from NASA are going to brief everybody in NASA in the next two months. They're covering the twelve centers with some nine briefings. They have already published some changes in their source selection procedure manual and they've issued their top policy document. They've also put out a paper that can be read in about minutes which tells of the change and the way they're going to do business as a result of A109. They're moving and they understand that it is serious. Other agencies have not rewritten A109 in implementing it, but have attached A109 to their implementing instructions. In a couple of cases, these implementing instructions reference OFPP 1, which talks about the application. In fact, one agency has an implementing instruction that is all on one page, which is certainly refreshing. This instruction defines a major system for that agency, appoints an acquisition executive, establishes an operating MSA review board, assigns responsibilities for program management appointments, and says to follow A109 and use OFPP 1 as a guide in implementation of A109.

Now let's take a look at another gap-that gap between the practitioner and the researcher. First, we'll look at the pull of the practitioner and the push by the researcher. For example, I'm going to acquire a new program manager who has just come out of the cockpit, or off the bridge, or out of the tank and I'm going to acquire a new major system following A109. I've just been appointed and have been through the school at Fort Belvoir for five months and have learned how we did major systems acquistion under 5001 and 5002 dated 1971. The project officer may not have the personal experience necessary, but it's recognized that everyone doesn't have it. Therefore, he's likely to ask the research group to assist him in the planning or give him a dump of the lessons learned and the applicable body of knowledge. His request is usually urgent, and unpredictable. It certainly would disrupt any research organization that is trying to do things in an orderly manner. As a result, some research organizations hire a "Belt-Way Bandit."

The Belt-Way Bandit is not all bad. I'll have to admit though, that I am the one who has converted the President's Memorandum into the memorandum that's been called "Death on Consultants." It really was not intended to be that by either the President or myself. It basically says that if they (Belt-Way Bandits) are necessary and appropriate, use them. If they're not, get rid of them. I understand some agencies have interpreted that to mean that there is moratorium and no more will be used. There's nothing wrong with using consultants but the Bandit tries to be a little bit creative. He just can't tell you to read your regulations and implement them. So he creates something. This "thing" gets the acquisition process skewed a little bit. Some of them are retired and still operating under 3200.9 if any of you remember that. That preceded 5001 of 1971. And that's not so funny. I've had some of these consultants come in and say that they really want to do some consultanting in order to help in this A109 process. The Bandits, as I said, need to be creative. They reinterpret the policy and the directions involved in it.

Whether the Belt-Way Bandits were involved or not is neither here nor there, but I'll just take a recent Navy system as an example of how things get skewed. A109 says pretty loud and clear that you do not go out to the industry with a need, get a response in their system designed concepts, bring those back and transfuse them, take the best features from each one, and then recompete it on the basis of the Government design or system designed concept. All the Admirals from the top on down said they were going to follow A109. RFQI came out of the Navy that had a statement of work which was to be performed and the resulting information was to be fed back to the Navy. That no sooner hit the streets than I got three phone calls from contractors that said, "hey, if this is A109 Fred, we don't want to play the game. This is gonna cost us up to 2 million dollars to respond to this and it says right in here that the information is going to be transfused. They want all our innovative ideas from which they're going to pick and choose and then issue us a solicitation."

So, we began to investigate. We had a little come to God session with DDR&E and Bob Berry and he had one with the Navy. The Navy then sent out a letter that said that was not their intent at all.

"You people in industry don't have to respond to this thing," the letter said. "You don't have to give us all your innovative ideas but if you do, we'll protect them. The RFP, when it comes out, will be intact, on the basis of need and will be evaluated accordingly, with no pre-determined solution on the part of the Government."

There was an example of everybody nodding their head, but then doing something else. I just had a recent discussion on another one that I noticed in our source of information in the OFPP, which is pretty good. It said the Air Force awarding a contract to McDonell Douglas for the follow on intercepter modification of the F15. I asked for the need statement because if we need a follow on intercepter, it should be documented. It might be better to modify an F14 to be that intercepter. That question has not been answered yet. I wrote a memorandum over to DDR&E and I'm sure that that push will result in a pull from the Air Force at least.

Now, a push by researchers must be anticipated and encompass lessons learned and be attractively packaged. Take a lesson from the merchandising people. I don't know if Paul McDonald is still here, but I see Martins here from US Management Inc. and I'll tell you their brochures are very attractive. That's marketing and merchandising. And that's what the researchers have to do.

Let's look at the pull by a researcher and a very weak push by the practitioner in the area of lessons learned from A109 implementation. There is little or no motivation on the part of the practitioner to document or provide lessons learned for the researcher so that he can expand the body of knowledge, analyze and evaluate. Therefore, it's up to the researcher to expand that body of knowledge by taking the initiative to gather the data, analyze it, evaluate, draw a conclusion, make recommendations, and market the product. To me, this is essential in the process; to build that body of knowledge; to disseminate it, and to advance the management technology for major systems acquisitions.

I have a lot of lessons learned that we might cover in the question and answer period, but in summary, lets swing the gates and the fences both ways. Let us recognize that each world in the universe has its unique problems and close these gaps between the researchers, the policy makers and the practitioners.

PROCUREMENT AND ACQUISITION PLANNING

A Comparative Analysis of the Application of Production Readiness Reviews

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INTRODUCTION

The independence of the United States can be maintained only if the nation is able to establish and support an adequate defense force. Existing weapon systems must be operationally ready and new technology must be fostered to insure that the operational military units can cope with any threat from a potential adversary. Other national priorities include a justifiable concern for the health, education and welfare of the citizenry. This multiplicity of needs means that the Department of Defense will receive limited resources with which to effect its defense mission.

The limitation on available resources means that the funds allocated for defense purposes must be expended in an efficient and effective manner. This requirement places a premium on adequate and timely planning. Each military service must require from each subordinate unit an accounting of funds expended and this necessitates the comparison of results against an initial goal. The mechanism for the introduction of the new technology and corollary weapon systems is the weapons acquisition process. As a consequence of the limited funding, acquisition and procurement planning become critical to each phase of the weapons acquisition process. Four primary decision points are now associated with the acquisition of a weapon system. Office of Management and Budget Circular No. A-109 has the impact of adding a Defense System Acquisition Review Council (DSARC) zero. This decision point involves the identification and definition of a specific mission need. DSARC 1 at the end of the conceptual phase revolves around the selection of a competitive system design for test. DSARC 2 subsequent to the validation phase involves a commitment to full-scale development and limited production. The most significant decision, however, is the DSARC 3 which commits the system to full production. For major systems; that is one with an estimated production cost exceeding $300 million, a production readiness review (PRR) is required.

The Production Readiness Review (PRR) is an Air Force procurement concept that evolved in the early 1970s to meet the demands of the dynamic weapons acquisition process. A PRR is a government analysis of a contractor's readiness to transition from the full-scale development phase into the production phase of the weapons acquisition process. The contractor may have produced some developmental hardware, but the question

addressed by the PRR is whether or not the contractor is ready to produce the required quantity of production units efficiently and economically. Air Force Systems Command (AFSC) defines the Production Readiness Review (PRR) concept as follows:

> The PRR is a formal inspection to determine whether (1) a system or equipment under development is ready for efficient and economical quantity production; (2) all important production engineering problems encountered during development have been resolved; and (3) the contractor has accomplished adequate planning for the production phase (4:1-2).

The purpose of this paper is to report the results of a study to determine, first, if significantly different PRR approaches have been used on major Air Force programs to date and, second, if a standard PRR approach is feasible for conducting future PRR programs.

BACKGROUND

Cost growth and large cost overruns on many military programs in recent years have generated severe criticisms in the press and in Congress. While inflation and an expanding technology are increasing the costs of weapon systems, the growing demand for public funds to support other government projects has resulted in a lesser proportion of the federal budget available for Department of Defense programs.

The acquisition of major weapon systems is designed to follow a systematic flow through well-defined phases. These phases are conceptual, validation, full-scale development, production, and deployment (see Figure 1). A major step was taken in 1969 to achieve better coordination of the various phases of the weapons acquisition process. The Defense System Acquisition Review Council (DSARC) was formed to evaluate and review each major weapon system at three critical junctures--DSARC I before transitioning into the validation phase, DSARC II prior to moving into the full-scale development phase, and DSARC III before moving into the production phase (see Figure 1).

The purpose of DSARC III is to provide a recommendation to the Secretary of Defense on moving a major weapon system into production. The DSARC III must confirm, among other points, "...that a practical engineering design, with adequate consideration of production and logistics problems, is complete." DSARC III serves as the basis for the decision on whether or not a weapon system will be produced for deployment. DSARC III meetings are held when the military department determines that engineering and operational systems development and testing have been substantially completed, all major development problems have been resolved, and the weapon system is ready to transition into production. For some of the newer major weapon systems (e.g., the F-16 program), a

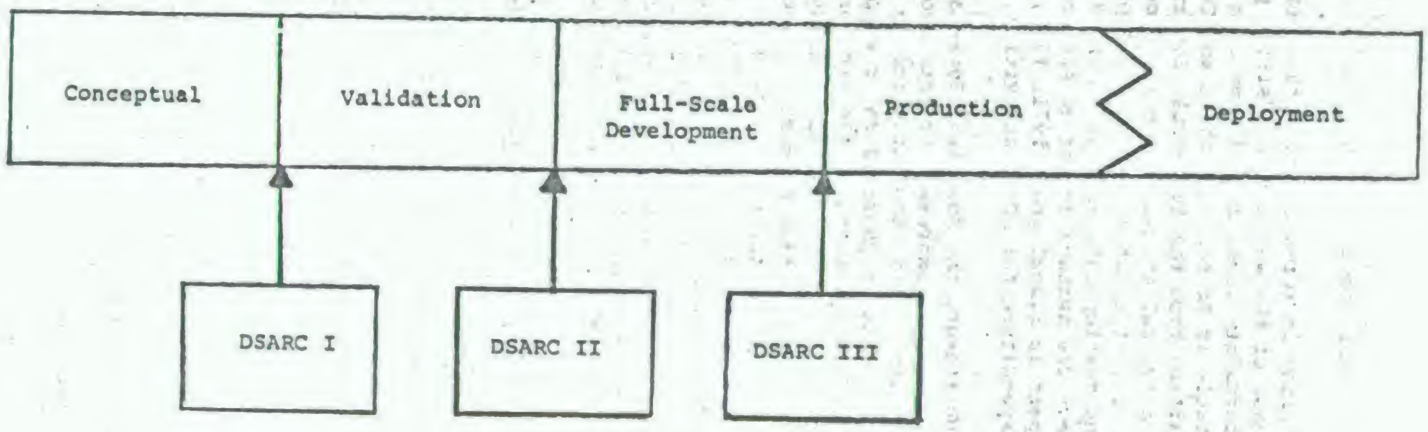

Fig. 1. Weapons Acquisition Process

DSARC IIIA is held prior to receiving long lead production authorization and a DSARC IIIB is held before full production go-ahead is received.

The most critical time period in terms of the rate of expenditure of funds is the production phase of the weapons acquisition process (see Figure 2). The technical uncertainty level should have been reduced by this time, and the major obstacle is to convince DSARC and Congress that the program is ready to transition from the full-scale development into production. One estimate of a typical Air Force program's costs, excluding operation and support costs, is that about 33 percent of a program's funds are committed for research and development, and the other 67 percent are spent in the production phase. The average amount of Air Force Systems Command production dollars spent in fiscal years 1971, 1972, and 1973 was 1.7 times greater than the expenditure for RDT&E activities.

In 1970, Mr. Philip N. Whittaker, the Assistant Secretary of the Air Force for Installations and Logistics, expressed concern about whether sufficient emphasis was being given within the Air Force to the preparation for and the management of the production phase of major weapon acquisitions. An Air Force study was conducted to determine if the Air Force had acceptable procedures to (1) accomplish production planning during the full-scale development phase of the weapons acquisition process, (2) formally document and review production criteria prior to the production go-ahead decision, and (3) continuously monitor the production program after the production decision is made. The study team conducted comprehensive reviews of Air Force Systems Command's production management activities in various field organizations, system program offices, and contractor plants. One specific recommendation was that the Air Force should conduct and document a formal Production Readiness Review (PRR) prior to the production decision.

The Air Force study group noticed an information gap when it came time to determine if a contractor was ready to transition from the development to production. At this stage many of the major weapon system relationships may be categorized as that of bilateral monopoly. The monopsonist is the government, and the monopolist is the sole-source contractor. The Air Force initiated the formal PRR procedure to obtain information for evaluating a sole-source contractor's readiness to make the development-to-production transition. An AFSC regulation (AFSCR 84-2) was published to cover application of the PRR concept.

Air Force Systems Command Regulation (AFSCR) 84-2 prescribes that the PRR team size and composition be established based on the scope of the review effort. Primary PRR team members normally possess expertise in the following functional areas: (1) industrial or production engineering, (2) production management, (3) program or project planning and production control, and (4) manufacturing methods, tool design and test requirements, plant layout, etc. Since the procurement process involves many related functional disciplines, the PRR team may need to be augmented by experts from other functional areas.

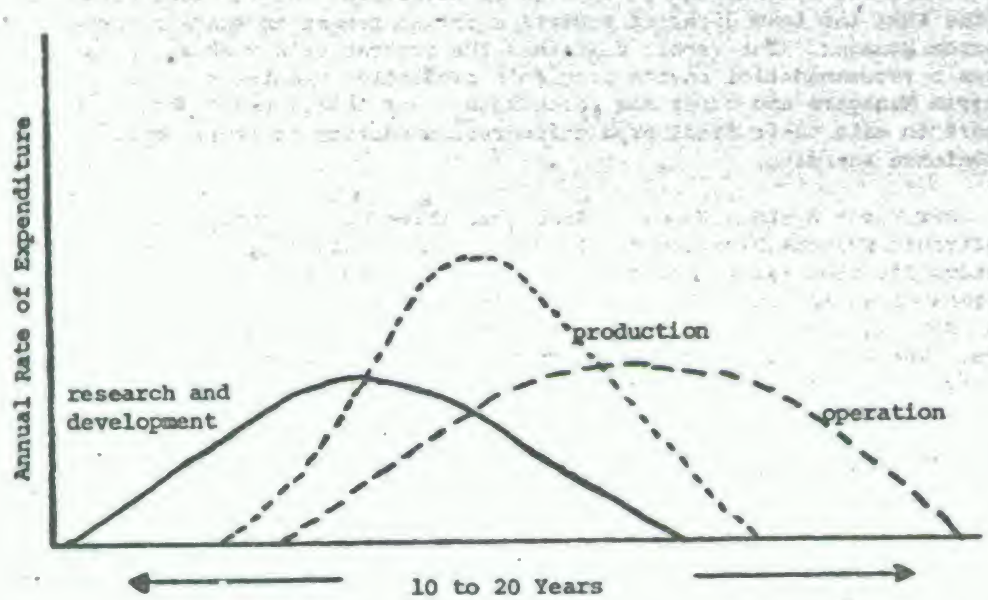

Fig. 2. The Flow of Expenditures in a Typical Weapons Program (2:310)

AFSCR 84-2 also states that the PRR team conducts an on-site examination of the contractor's working papers, documents, production methods, processes, and techniques. To assess the contractor's readiness to transition into production, the PRR team examines existing data and procedures. The PRR team uses predetermined criteria as standards to conduct an orderly, penetrating, and conclusive review. AFSCR 84-2 contains twenty-five evaluation criteria or questions to be used in conducting PRR programs (see Figure 4).

AFSCR 84-2 further stipulates that if a contractor does not meet acceptable standards, then corrective action within the scope of the contract may be required. The contractor's weak areas are identified, and a schedule for subsequent reviews is developed. At the conclusion of the PRR, the team director submits a formal report to the Air Force Program Manager. The report describes the contractor's weak areas and gives a recommendation on the program's production readiness status. Program Managers and other Air Force management levels use the final PRR report to make their final production recommendation to other Department of Defense agencies.

Air Force Systems Command (AFSC) has three major product divisions -- Electronic Systems Division (ESD), Hanscom AFB, Massachusetts; Aeronautical Systems Division (ASD), Wright-Patterson AFB, Ohio; and Space and Missile Systems Organization (SAMSO), Los Angeles, California. Production Readiness Reviews have been conducted by each of these three divisions in some form. The PRRs which have been completed or are in progress are shown in Figure 3.

RESEARCH DESIGN AND DATA ANALYSIS

The research effort had two objectives. The first objective was to analyze the PRR programs that had been completed on major Air Force weapon system programs to date to determine what disparities, if any, existed among the PRR approaches. The second objective was to determine if a standard PRR approach was feasible to satisfy Air Force Systems Command requirements.

Since Production Readiness Reviews (PRR) are unique to Air Force Systems Command (AFSC) procurement activities, the universe for the research consisted of those major weapon system programs that were required to adhere to AFSCR 84-2 and which had an estimated Research, Development, Test and Evaluation (RDT&E) cost exceeding $75 million or an estimated production cost exceeding $300 million. Two populations were identified within the universe. Population I consisted of those major AFSC weapon system programs that had completed an entire PRR program and had met a DSARC III review. Population II consisted of those AFSC major weapon system programs that are presently conducting PRR programs or will be required to conduct PRR programs in the future.

Figure 3

Production Readiness Review Programs

AFSC Procuring Division	Number PRRs Completed or in Progress	Air Force Programs
ESD	1	AWACS
ASD	5	B-1 A-10 F-15 F-16 ARC 164
SAMSO	2	Minuteman Mark XII Shroud Communications Satellite/TRW

A census of Population I was conducted. Population I consisted of three major weapon system programs: (1) Airborne Warning and Control System (AWACS), which is being procured by AFSC's Electronic Systems Division, Hanscom AFB, Massachusetts; (2) F-15 System, which is being procured by AFSC's Aeronautical Systems Division, Wright-Patterson AFB, Ohio; and (3) A-10 System, which is being procured by AFSC's Aeronautical Systems Division, Wright-Patterson AFB, Ohio. The three major weapon system programs have gone through the entire PRR process. Data collected on each PRR program included: the number of PRR visits to prime contractor, PRR visits to subcontractors, different skills (System Program Office), PRR team members (SPO), PRR team members (Air Force Plant Representative Office), different skills (AFPRO), supplemental PRR team members, duration of PRR program, verbatim AFSCR 84-2 PRR questions, additional PRR questions, estimated PRR program cost (SPO), and estimated PRR program cost (AFPRO). The data were used to objectively assess if differences existed in the conduct of the three major PRR programs completed to date.

The authors were able to statistically show that significant PRR program variations existed for the F-15, A-10, and AWACS programs. Some notable examples include the following: (1) the AWACS program office made three major visits to the prime contractor to conduct its PRR program, whereas the F-15 and A-10 program offices made over twenty visits to their respective prime contractors solely to conduct PRR program activities; (2) the F-15 program office made approximately fifty visits to subcontractors to conduct PRR program activities, while the A-10 and AWACS program offices held considerably fewer subcontractor PRR meetings; and (3) the F-15 PRR program was conducted in five months, whereas the A-10 and AWACS PRR programs lasted thirty and twenty-nine months, respectively.

AFSCR 84-2 contains twenty-five PRR criteria which are to be used to assess whether or not a major weapon system is ready to make the development-to-production transition. To determine if a standard PRR approach is feasible, ten Air Force Systems Command (AFSC) production management experts were requested to prioritize the twenty-five AFSCR 84-2 questions. The AFSC production management experts were required to possess the following qualifications: (1) active in the production management area for at least three years, (2) involved in the management of major Air Force weapon systems for at least five years, and (3) involved in the planning or implementation of at least one AFSC PRR program. The key determinant for selecting the production management experts was their previous PRR experience.

If the ten AFSC experts agreed on the relative importance of evaluating the production management areas covered in the twenty-five AFSCR 84-2 PRR questions, then this would provide support for the hypothesis that a standard approach is feasible for the conduct of future Production Readiness Review (PRR) programs. The ten AFSC production management experts were requested to independently rank order the twenty-five AFSCR 84-2 PRR questions. Each expert assigned a "one" to the PRR

question that was considered most important and a "twenty-five" to the AFSCR 84-2 PRR question of least importance. The primary nonparametric statistical test used for evaluating the agreement among the ten AFSC experts for the twenty-five AFSCR 84-2 PRR questions was the Friedman two-way analysis-of-variance-by-ranks test. To provide additional support for the results obtained from the Friedman test, two additional statistical tests were performed. The second test was the nonparametric Kendall Coefficient of Concordance W, and the third statistical test used for verification purposes was the parametric F test using the Air Force Institute of Technology's Omnitab II computer program.

Both nonparametric statistical tests--the Friedman two-way analysis-of-variance-by-ranks test and the Kendall Coefficient of Concordance W--and the parametric F test in the one-way analysis of variance supported the same conclusion that the ten AFSC production management experts did agree on the application and importance of the twenty-five AFSCR 84-2 PRR questions. The prioritized list of PRR questions from the most important to least important is provided in Figure 4.

Several corollary findings resulted from the research. These findings are based on collected data, review of Air Force publications pertaining to PRR, discussions with production and procurement personnel who have been actively involved with PRR activity, and the researchers' interpretations of their studies and observations.

First, an attempt was made to conduct an initial survey concerning the following question: When should the PRR program activity actually begin in the weapons acquisition process? The ten AFSC production management experts were requested to indicate prior to which DSARC's (i.e., DSARC I, II, and/or III) should the twenty-five PRR questions be evaluated. The ten AFSC experts agreed that all twenty-five PRR questions should be evaluated prior to DSARC III. And five or more of the ten AFSC production management experts agreed that twenty of the twenty-five AFSCR 84-2 PRR questions should be evaluated prior to DSARC II. The consensus of the ten AFSC production management experts was that initial PRR activities should be conducted much earlier than just prior to the preparations for the DSARC III decision-making process.

Second, the general consensus of the personnel interviewed was that there is a lack of readily available documentation on how previous PRR programs have been conducted to date. No readily accessible lessons-learned information is available for those programs that are now required by AFSCR 84-2 to conduct PRR programs. Historically, it has been incumbent on each system program office to determine what previous PRR programs had been conducted, contact personnel who had been involved in those previous PRR programs to determine what had actually been accomplished, and finally develop a new PRR program plan, using their research information as a baseline, that would best fit their particular program.

Figure 4

AGGREGATE PRIORITY LIST OF TWENTY-FIVE AFSCR 84-2 PRR QUESTIONS FROM TEN AFSC PRODUCTION MANAGEMENT EXPERTS

Ranking	Current Question Number	AFSCR 84-2 PRR Question
1	6	Adequate advanced production planning has been accomplished and required production controls established to ensure timely production.
2	2	Engineering problems encountered during development have been resolved with appropriate trade-offs against stated operating requirements so that production costs/schedules are optimized.
3	1	Milestones which demonstrate the achievement of a practical and producible engineering design have been met.
4	13	Results of technical reviews and the production impact of unresolved problems and risk have been assessed.
5	5	System configuration has been reviewed to determine if any significant design changes will be required for manufacturing.
6	14	Test program results and the status of qualification testing to determine production impact and risk have been evaluated.
7	19	Production or manufacturing capabilities of major subcontractors and vendors have been technically evaluated and found adequate.
8	9	Assurance of readiness of the manufacturing and production equipment, methods, facilities, test and training equipment, and status of accessory and ancillary items.

Ranking	Current Question Number	AFSCR 84-2 PRR Question
9	3	Critical production engineering and production tooling have been demonstrated to prove that engineering has been satisfactorily accomplished.
10	4*	Acquisition will smoothly transition from full-scale development to production.
11	10*	Planned production schedules reflect economy of operations and minimize financial commitments until all major development problems have been resolved.
12	12	Change activity during development has been evaluated and the impact of outstanding changes on production has been assessed.
13	15	Specifications and drawings have been reviewed to assure their adequacy for the planned production phase.
14	11	A thorough assessment of the make-or-buy structure has been accomplished and procedures exist so control and visibility of the vendors and subcontractors can be effectively maintained.
15	21	Quality controls and inspection procedures have been established for materials treatment or processes to be used in production.
16	25	Planning has been made to assure timely release of manufacturing instructions.
17	16	Application of production tooling and test equipment to manufacturing during development has been assessed and the application of same to the production phase has been defined.

*Indicates tied pair of mean rankings.

Ranking	Current Question Number	AFSCR 84-2 PRR Question
18	18	Production management systems used for providing management with timely production status information are effective.
19	17	Material management system for determination of requirements, procurement, receiving, inspection, materials handling and storage, inventory control, control of finished goods, and shipment is adequate.
20	7	A systematic approach to standardization has been accomplished in the design process and parts selection to maximize the use of military standard components, parts, and processes consistent with the system requirements.
21	20**	Constraints of laboratory or model shop capabilities versus quantity production requirements have been fully considered.
22	22**	Assessment of the GFP or services requirements, controls, management, and availability of suppliers has been accomplished.
23	24	The contractor is adequately organized to accomplish the production requirements.
24	23	Availability of production labor skill requirements has been assessed and their acquisition adequately planned.
25	8	Product assurance controls and tests to prevent manufacturing degradation of performance parameters have been established.

**Indicates tied pair of mean rankings.

Third, AFSCR 84-2 is directed at major weapon system programs, as defined by DOD Directive 500.1. The AFSCR 84-2 does not provide much assistance for the smaller Air Force Systems Command programs which are just under the threshold levels. But, personnel for the smaller programs are still tasked to make an assessment about the contractor's readiness to transition from full-scale development to production. Several interview respondents expressed the opinion that a mini-PRR program should be conducted on the smaller programs.

And fourth, information gleaned from a background review indicated that the Air Force is the only military department that conducts a PRR prior to movement into production. The other military departments conduct continuous surveys and analyses, but no formalized procedure has been developed to accomplish the task. Additional interviews conducted after the initial background review produced similar results. Based on the authors' research findings, the Air Force remains as the only military department which has a formal PRR procedure. Since movement into production is very critical and expensive, the other military departments should consider establishing similar procedures.

CONCLUSIONS AND RECOMMENDATIONS

The PRR approaches used to date have been different. The specific reasons for using the different approaches could not be determined. But, the conclusion is that it should not be necessary to start at the beginning for every aspect of a new PRR program. At least some factors or activities should remain essentially the same for future PRR programs.

The data collection and analysis indicated that the ten AFSC production management experts did agree on the relative importance of the twenty-five PRR questions. This conclusion provided support for the hypothesis that a standard PRR approach is feasible for application.

The use of the PRR is relatively new, and application of the technique is primarily concentrated on the major Air Force weapon system programs. Although only three Air Force PRR programs have been completed to date, many more Air Force program offices will be required to conduct PRR programs. For example, the F-16 System Program Office is presently conducting its PRR program.

The authors recommend that future PRR programs be developed around the prioritized list of twenty-five AFSCR 84-2 PRR questions (refer to Figure 4). The questions at the top of the prioritized list should receive the most emphasis in future PRR programs; the lower-ranking questions should receive lesser emphasis. Future PRR program organizers should acknowledge the critical importance of accomplishing the top six questions. The future PRR program planners should recognize that a considerable amount of PRR program effort should be spent on insuring that most engineering

and testing activities have been accomplished prior to the production phase of the acquisition process. The contractor can be initially approached with the six high priority questions. The remaining nineteen questions can be broken into sections as determined by the individual system program office. The researchers acknowledge that some new PRR evaluation questions may be generated. These new questions can be placed in the baseline prioritized list as determined appropriate for the individual PRR program.

Another specific recommendation is that initial PRR planning and evaluation activities should begin as early as DSARC II. Two of the three major weapon system program offices which have completed PRRs to date spent approximately thirty months on the PRR program. This recommendation is based on the finding that the PRR program should actually begin early in the weapons acquisition process rather than just prior to DSARC III. An incremental approach is recommended in which the entire PRR program effort is conducted in stages that will coincide with other program activities. This incremental approach has proven successful on PRR programs which have been conducted to date.

Some additional factors are provided below that should be considered in future PRR programs:

1. The system program office (SPO) should insure that adequate contractual coverage is secured for all contractors (i.e., prime contractor and subcontractors) involved in the PRR program.

2. A PRR preproduction meeting should be held early enough in the PRR program to bring all the participants together to discuss the PRR program plan and the specific implementation of the plan. The convention should prevent many potential problems downstream.

3. The PRR program should be tailored to the individual program characteristics using the prioritized list of AFSCR 84-2 PRR questions and the other specific recommendations above as a baseline model.

4. If subcontractor PRRs are conducted, a prime contractor representative should be in attendance at each to prevent the government from inadvertently assuming a position between the prime contractor and his subcontractors.

5. When the PRR team visits a contractor, the team leader should make explicit remarks in the initial and exit briefings that the contractor should assume no contractual direction from the comments or actions of any of the PRR team members. All direction should be given by the Procuring Contracting Officer to the prime contractor.

6. The SPO and contract management organizations should begin PRR planning early in full-scale development in order to complete the PRR effort prior to DSARC III. Sufficient time should be allowed for schedule slippages, contractor revisits, and Department of Defense Product Engineering Services Office (PESO) visits.

7. The Air Force Program Manager should direct all SPO personnel to consider their support to the PRR effort as being a very high priority task.

8. The SPO should utilize experienced personnel (e.g., Air Force Materials Laboratory (AFML), previous PRR program experts, etc.) to conduct a comprehensive PRR of the weapon system program.

9. The PRR team should be specifically tailored to evaluate the particular contractors, equipment, manufacturing processes, etc. under review.

10. The PRR subject should be addressed early enough in the weapons acquisition process to insure that producibility and production readiness considerations are included in engineering preliminary design reviews and critical design reviews.

11. A systematic approach should be developed to handle the administrative workload caused in managing a PRR program.

12. Government communication with subcontractors concerning PRR program activities should be conducted through the prime contractor and not directly to the subcontractors.

13. The SPO's routine communication with the secondary delegated contract management organizations should be conducted through the prime contract management organization. As a minimum, the SPO should keep the prime contract management office informed of the SPO and secondary contract management office's activities.

14. The SPO should document PRR program activities. Background documentation that is used as a basis for the final report to the Air Force Program Manager should be prepared to provide backup justification for the recommendations in the final PRR report.

15. The SPO and AFPRO should determine the availability of existing data sources and utilize the available data to support PRR activities (e.g., pre-award surveys, AFCMD Contractor Management System Evaluation Program, should cost, source selection data, etc.).

As of the writing of this study report, the Air Force is the only service to have developed a formalized PRR procedure to assess a contractor's readiness to make the transition from full-scale development to production. The experience on the three Air Force programs--F-15, A-10, and AWACS--that have completed PRR programs has been encouraging. All three major weapon system programs received favorable DSARC III decisions and were authorized to proceed into the production phase. The interview respondents

were unanimous in agreeing that the PRR technique is beneficial and should help prevent many potential problems in the production phase of the weapons acquisition process. Due to the critical nature of the development-to-production transition process and the large amount of taxpayers' dollars which will be obligated when production go-ahead is authorized, it is recommended that the other military services develop similar Production Readiness Review (PRR) procedures to insure that a contractor is ready to go into production.

CONCLUDING OBSERVATIONS

After analyzing the Air Force's PRR technique, the authors conclude that the PRR technique has merit. First, the Air Force can be more assured that planned major weapon systems will receive a positive DSARC III and Secretary of Defense approval on full production go-ahead. Three major Air Force weapon system programs--A-10, F-15, and AWACS--which have completed a PRR program have received production authorizations. Second, after completing a PRR program effort, the Air Force buying activity can feel more confident that a contractor is ready to make the development-to-production transition. The impact is that many potential problem areas will be corrected early in the weapons acquisition process, and the possibility of a major weapon system procurement fiasco will be reduced. And finally, there will be more Air Force and contractor interaction and involvement early to guard against potential problems that could be encountered in the production phase of the weapons acquisition process. The United States taxpayers will be the primary beneficiaries of the PRR program activities.

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MIXED PROCUREMENT AND THE MANAGEMENT OF RISK

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1. INTRODUCTION

"Versatility Planning" and "High-Low Mix" have recently become highly important to the Department of Defense. This paper will present a method of analyzing High-Low Mixes (and related procurement strategies) in a context of Versatility Planning.

Section 2 will discuss Versatility Planning and the lack of methods to implement it. We will also consider the "High-Low Mix" as an example of something we call "Mixed Procurement," which is the purchase of more than one system to perform a given mission. This section will demonstrate that constrained optimization under certainty will not lead to a mixed procurement solution. We therefore will conclude that current methods are not suitable for planning for versatility, nor are they adequate to analyze mixed procurements.

Section 3 will propose a solution to both problems. We will borrow heavily from portfolio theory to purpose a method of selection, mixed procurement, and versatility planning context. Portfolio theory deals with the selection of optimal mixes (portfolios) of risky assets (e.g., common stocks) by rational, risk-averse investors (Modigliani and Pogue, 1974). We will treat weapon systems as risky assets, whose performance varies according to the operational situation. Our Portfolio Theory approach leads to mixed procurement solutions, and provides a conceptual basis for undertaking Versatility Planning.

Section 4 will illustrate by example the arguments in Sections 2 and 3. Section 5 will consider two policy implications of this approach. First, we will use the portfolio method to demonstrate a means of estimating the maximum acceptable development cost of a system with known performance and non-development cost characteristics. Second, we will consider the model's implications for intelligence estimates. We believe that intelligence data should be processed to emphasize the range and likelihood of various future technical, operational, threat, and political variables--rather than just produce most-likely estimates.

2. SOME CURRENT DIFFICULTIES

Procurement decisions are never made in a vacuum. We acquire weapons systems in response to operational needs. Decisions to acquire and operate new systems must, therefore, fit into the general defense planning scheme. It also follows that our acquisition strategy must be responsive to the overall needs of the defense establishment and our national policy objectives.

We are now becoming aware that defense planning must systematically provide for the wide variety of future scenarios in which our forces may have to be employed. The objective is not only to attain capable forces, but also to attain "versatility" of performance across the entire range of future military environments. The

name for this is Versatility Planning, a concept for future defense planning.

Despite its importance, the defense planning community has not yet undertaken to provide versatility planning analysis. This view was stated by Seth Bonder in his Keynote Address to the 37th Military Operations Research Symposium.

> . . .Senior defense managers are (or should be) interested in retaining the availability of options for defense forces. . . .the way cost-effectiveness analysis is practiced in the DOD doesn't provide this. I am not aware of any decision-theoretic efforts to describe formally the concept of versatility planning or to prescribe how it might be implemented. (Bonder, 1976)

For a number of reasons, the DOD finds itself dealing with the procurement, or proposed procurement, of "High-Low" mixes. We find it interesting, therefore, that the term is not defined precisely in current literature. The basic meaning is fairly clear: the purchase of high-capability, high-cost items combined with lower capability, lower-cost items to accomplish the same basic mission. We still find the lack of precision disturbing, and consider it to be not merely a matter of semantics. In the interests of more systematic analysis of the subject, we will offer the more general term "mixed procurement," since any two systems need not be of a High-Low character.

Since we are buying systems to accomplish the same mission, we will assume that the systems thus procured are perfect substitutes for each other. For purposes of this discussion, we therefore offer the following definition: mixed procurement is the acquisition of two (or more) systems that are perfect substitutes in any given operational environment.

The foundation of most of economic analysis of defense problems lies in the solution of a constrained optimization problem, which can take either of two logically equivalent forms. The first is constrained maximization, which is stated as

$$\text{maximize } V(X,Y)$$

$$\text{subject to } C(X,Y) = \overline{C}\ , \tag{1}$$

where V is an effectiveness measure,

X and Y are military inputs,

C is a cost function which relates the inputs X and Y to resources expended (usually dollars),

and $\overline{C}$ is the budget limit.

This approach appears, for example, in Design-to-Cost methods. (Bonder, 1976) It is suggested as a possible criterion for analysis in DOD's Economic Analysis Handbook as "most effectiveness for a given cost constraint." (DEAC, 1975) It also appears as the "cost fixed" criterion in The Economics of Defense in the Nuclear Age. (Hitch and McKean, 1960)

The other form of the problem is constrained minimization, which is of the form

$$\text{minimize } C(X,Y)$$

$$\text{subject to } V(X,Y) = \overline{V} \,, \tag{2}$$

where $\overline{V}$ is a required level of effectiveness.

This approach appears in Design-to-Requirements methods. (Bonder, 1976) It is suggested as a criterion by the Defense Economic Analysis Council (DEAC) as "Least Cost for a given level of effectiveness." (DEAC, 1975) It also is proposed as the "Gain Fixed" criterion by Hitch and McKean. (Hitch and McKean, 1960).

The approaches are logically equivalent, in that both generate efficient solutions. Every constrained minimization solution contains a constrained maximization solution, and conversely. For example, if the minimum cost of attaining 1500 units of effectiveness is one billion dollars, then the maximum attainable effectiveness with one billion dollars is 1500 units.

With our terms defined, we can now state our first major conclusion: Constrained optimization under certainty will not support mixed procurement. To support the conclusion, it is first necessary to examine "perfect substitutes" in a bit more detail. For perfect substitutes, we can write the effectiveness measure in the following form

$$V_i = r_X X + r_Y Y \tag{3}$$

where V_i is effectiveness in the ith scenario,

X and Y are the amount of Systems X and Y acquired,

and r_X, r_Y are the per unit effectiveness of systems X and Y, respectively.

Actually, we are asserting only that Equation (1) is a suitable proxy for decision-making. The significance of the subscript, i, for the effectiveness measure will be discussed in later sections. We can graph effectiveness as a function of amount X and Y as shown in Figure 1. (Bilas, 1967) Any given level of effectiveness can be attained by any combination of X and Y lying on a straight line with slope $-\frac{r_X}{r_Y}$.

Let's now consider a constrained maximization problem of the form

$$\text{Max } V_i = r_X X + r_Y Y \tag{4}$$

subject to $p_X X + p_Y Y = \overline{C}$

where p_X and p_Y are the (known) costs of systems

X and Y, respectively,

$\overline{C}$ is the budget limitation,

and other terms have been previously defined.

Graphically, we can show the budget constraint as in Figure 2, where the budget constraint is portrayed as a straight line with slope $-\frac{p_X}{p_Y}$. If $\frac{r_X}{r_Y} > \frac{p_X}{p_Y}$, we have the situation given in in Figure 3, where the highest attainable effectivenesss occurs at the point $(x,y) = (\frac{\overline{C}}{p_X}, 0)$. Similarly, if $\frac{r_X}{r_Y} < \frac{p_X}{p_Y}$ then the highest attainable effectiveness occurs at the point $(x,y) = (0, \frac{\overline{C}}{p_Y})$. If the special case $\frac{r_X}{r_Y} = \frac{p_X}{p_Y}$ occurs, then the lines of equal cost and equal effectiveness are parallel and the highest attainable effectiveness can be achieved anywhere along the budget constraint line. In this instance, the decision-maker may choose to purchase only System X, only System Y, or any combination of the two within his constraint. However, he would <u>never</u> pay a positive cost for the privilege of purchasing a second system. This establishes our conclusion.

Given that currently established means of anlysis will not lead to a mixed procurement solution, and given that we are, in fact, engaged in mixed procurement, we are left with the uncomfortable conclusion that the nature and numbers of the systems in current mixed procurements are determined mainly by informal judgment, or by informally imposed constraints.

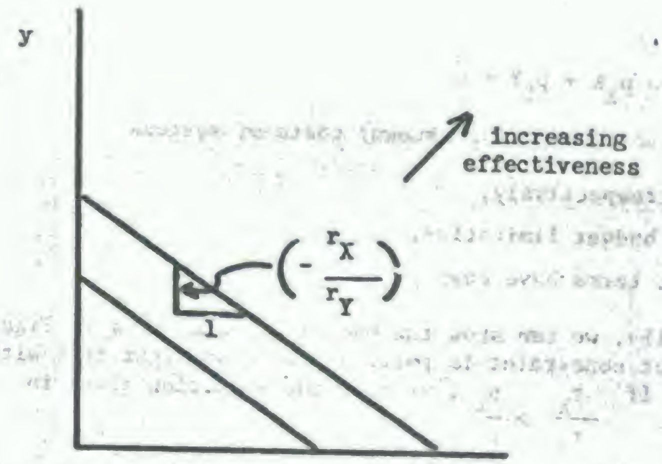

Figure 1.

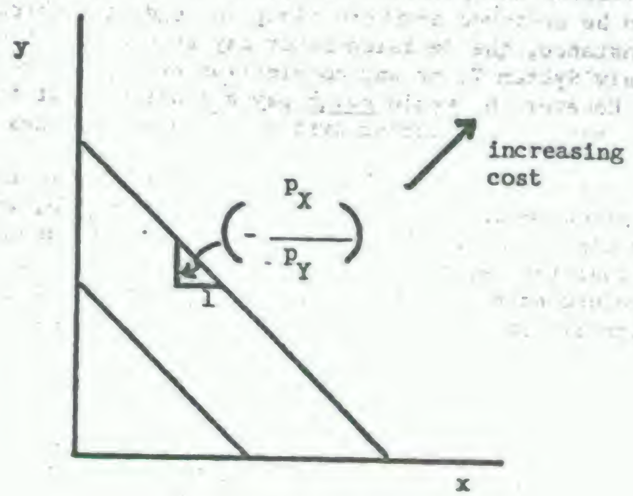

Figure 2.

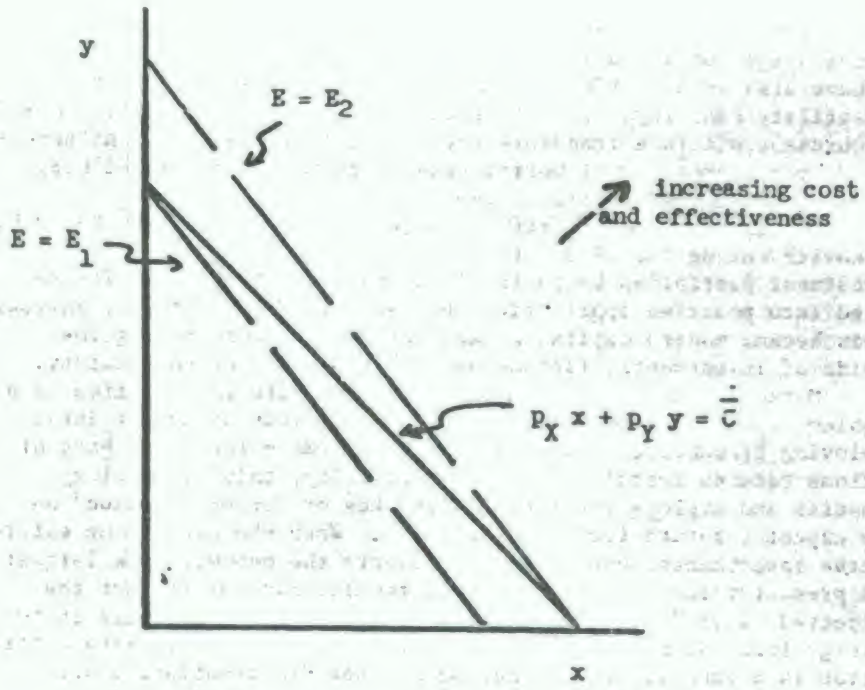

Figure 3.

3. THE PORTFOLIO THEORY APPROACH

We have now examined the standard constrained optimization approach and concluded that it cannot analyze mixed procurements. We have also seen that current methods are also inadequate for Versatility Planning. In this section, we propose to analyze mixed procurement within a framework for Versatility Planning. As advertised, our approach will borrow heavily from an established body of knowledge called Portfolio Theory.

The essentials of Portfolio Theory were developed by Harry M. Markowitz during the 1950's to describe the selection of optimal investment portfolios by rational risk-averse investors. Translated into positive applications by James Tobin and others, Markowitz's ideas became modern capital market theory, revolutionizing the fields of investments, finance and the economics of uncertainty.

Markowitz developed his approach to portfolio selection as a problem of utility maximization under conditions of uncertainty. Employing probability distributions to estimate the likelihood of various returns accruing to a given security, this methodology computes and employs the central tendency or "expected value" as the expected return from that security. When choosing among alternative investments, one logically selects the one with the largest net present value. However, actual results may not reflect the "expected value." The extent to which actual return is likely to diverge from the mean or "expected value" of the probability distribution is a function of the spread of that distribution, a spread measured statistically by its variance or standard deviation (which is the square root of the variance). The tools of mean and variance are employed to forecast expected rate of return and to measure uncertainty.

Portfolios are defined as combinations of two or more assets (securities). Conceptually, a portfolio could be developed by an investor to either increase expected returns at a fixed level of acceptable risk or to decrease the risk associated with attaining a target level of expected returns. A portfolio's expected return is the weighted average of expected returns on its component securities, using the proportions invested as weights $\left(E_p = \sum_{i=1}^{n} X_i E_i\right)$.
Its standard deviation depends on the standard deviations of return on the portfolio's component assets, their correlation coefficients, and the proportions invested:

$$\sigma_p^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} X_i X_j C_{ij} \quad \text{or} \quad \sigma_p = \sqrt{\sum_{i=1}^{n} \sum_{j=1}^{n} X_i X_j C_{ij}} \qquad (5)$$

where C_{ij} is the covariance between the i^{th} and j^{th} assets.

This covariance factor, when scrutinized, yields important insights into the ability of investors to reduce risk by careful selection of assets to be included in the portfolio. Basically, assets whose rates of return under the various plausible scenarios or states or nature are not too highly positively correlated can be combined to form portfolios which provide a smaller variance of expected return—less risk—than any one of the assets taken alone. We can, in fact, reduce risk through careful portfolio selection.

In standard portfolio theory risk is partitioned into systematic variability of return and unsystematic variability of return. Systematic variability is caused by factors which are associated with the market, the scenarios which may pertain (e.g., inflation); unsystematic risk is definitionally peculiar to the asset and not associated with market forces (e.g., poor management of the firm). Systematic risk is the focus of our inquiry and is the risk that can be reduced through combining assets which are less than perfectly positively correlated into a portfolio. A simplistic example involving two perfectly negatively correlated assets yielding returns between 30 percent and zero will illustrate the fundamental concept. Given an equal investment in each asset, the return profiles are shown in Figure 4:

(Insert Figure 4)

While the return on each asset ranges between 30 percent and zero as the various states of nature are assumed, the return on the portfolio is a constant 15 percent. This is due to the perfect negative correlation assumed in the example. Note that risk, as measured by variance of expected returns, is zero in the illustrative portfolio because the expected portfolio returns under any of the possible states of nature is 15 percent. This graphically demonstrates the power of the covariance concept in reducing risk (though finding perfectly negatively correlated assets is not an easy task!)

If alternative portfolios are examined for risk (σ_p), and expected return (E_p), and the dominance principle applied, an

Covariance Example

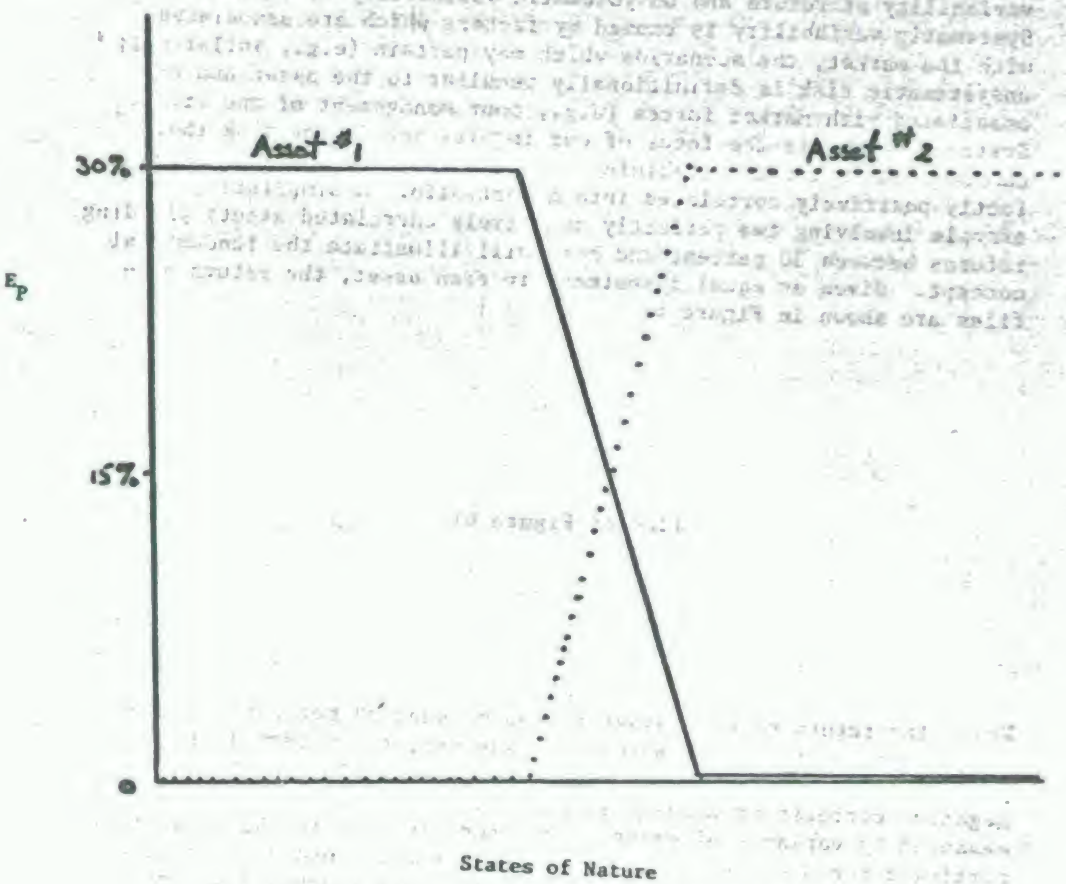

Figure 4

efficient frontier emerges. That frontier consists of dominant portfolios for any given set of risk and return coordinates as illustrated in Figure 5:

(Insert Figure 5)

That is, all points lying below the efficiency frontier are dominated by a point on that curve which offers more return for identical risk of less risk for the same return. Only undominated portfolios lie on the efficient frontier. The portfolio selection problem emerges as a straight-forward optimization, which involves:

(1) One or more decision variables (i.e., n assets);

(2) One or more constraints; and

(3) An objective function to be maximized or minimized.

Each investor is intent upon securing that portfolio which both lies upon this efficiency frontier <u>and</u> is on his highest indifference curve which possesses a point of tangency with that efficiency frontier.

(Insert Figure 6)

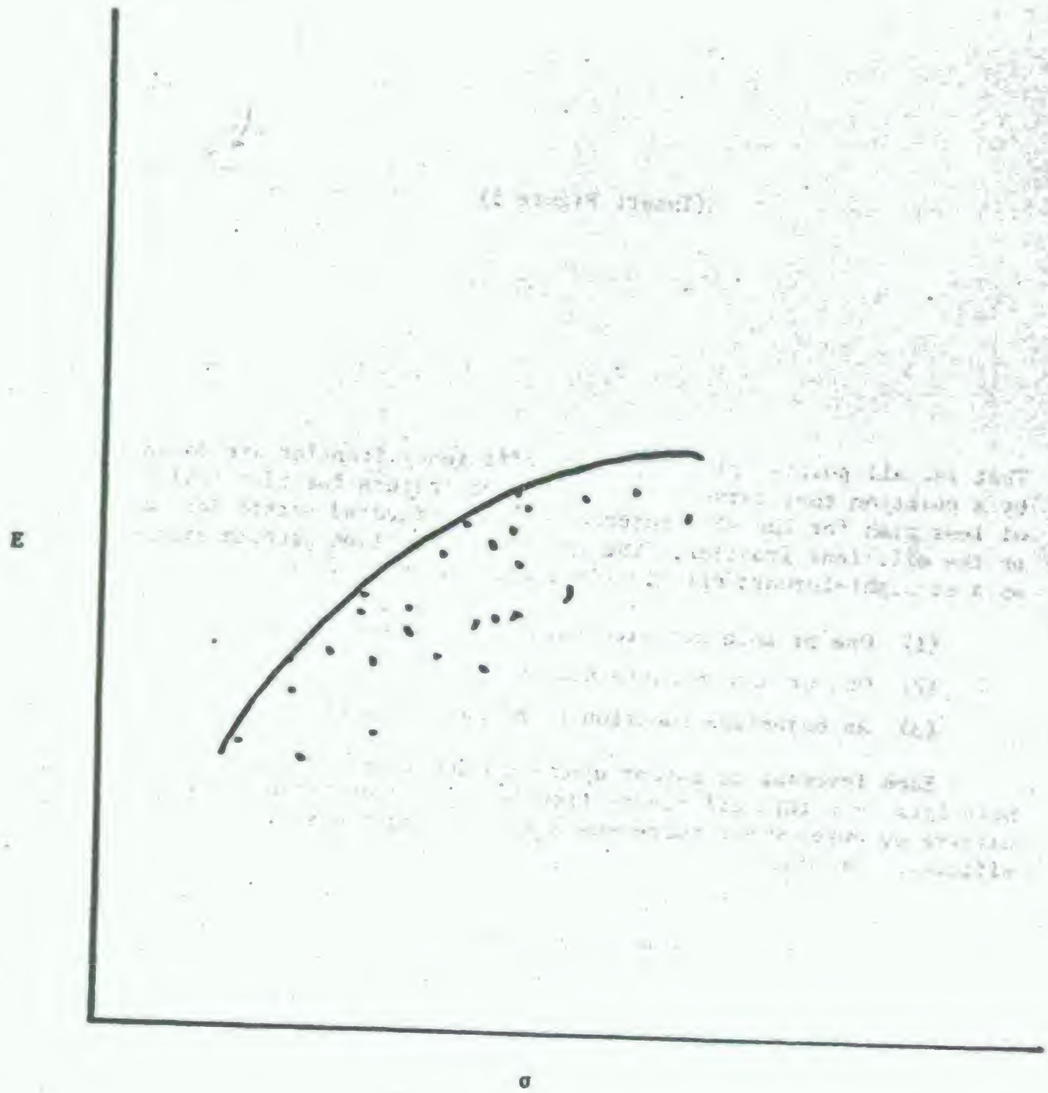

Figure 5

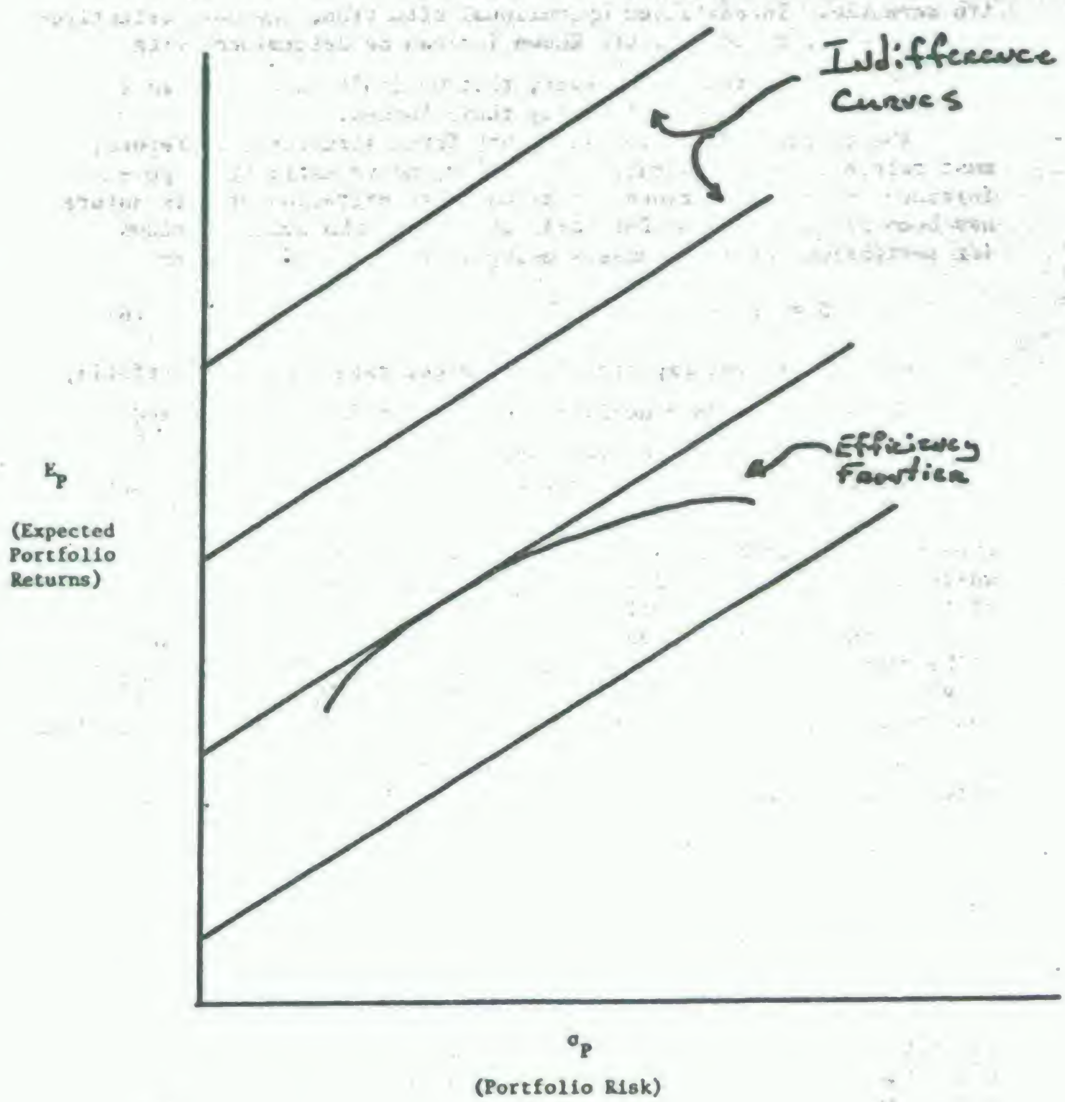
Indifference
Curves
Efficiency
Frontier
E_p
(Expected
Portfolio
Returns)
σ_p
(Portfolio Risk)

Figure 6

Given the curves in Figure 6, the investor selects portfolio A because it maximizes his satisfaction. In the section which follows, these elements of portfolio theory will be applied to selection of weapon systems which serve similar purposes.

The objective of Versatility Planning is to acquire a force which is not only capable, but which performs at least reasonably well throughout the range of probable operational environments.

In Section 2, we spoke of evaluating effectiveness in some ith scenario. In any given operational situation, the unit effectiveness measures, r_X and r_Y, are known (or can be determined) with certainty. The point is, however, that we don't know under what state (or scenario) we will employ these forces.

The criterion for evaluating any force structure, therefore, must relate to both "overall" capability and versatility of performance throughout various scenarios. One criterion of this nature has been proposed by the Portfolio Theorists, who evaluate mixes (or portfolios) of risky assets using a criterion of the form

$$U = E_P - \lambda\sigma_P \tag{6}$$

where E_P is the expected, or average, return of the portfolio, σ_P is the standard deviation of the portfolio return, and λ is a measure of risk aversion. When all other things are equal a larger E_P and smaller σ_P is desirable (to risk-averse decision makers).

Expected return, E_P, is a measure of "overall" portfolio capability while the portfolio standard deviation, σ_P, is an inverse measure of the portfolio's versatility.

We intend to treat various weapons systems as risky assets (like common stocks), which perform well in some circumstances and less well in others. Therefore, we will treat the unit effectiveness measures, r_X and r_Y, as random variables which can vary according to the operational scenario. We can, therefore, consider the unit effectiveness measures to be of the form

$$r_X = r_X(\theta)$$

and

$$r_Y = r_Y(\theta)\ , \tag{7}$$

where θ is a collection (vector) of random variables which describes the future state of the world. Various parts of this collection would include factors relating to operational, technical, political, and other attributes of any possible combat scenario. (Bonder, 1976) Since some scenarios are more likely than others,

we will assume that the possible states of θ are described by some joint probability function which measures those likelihoods.

With this data in hand, we can then treat weapons systems just as we treat risky financial assets. Knowing $r_X(\theta)$, $r_Y(\theta)$, and the correlation between r_X and r_Y, we can reformulate the constrained optimization problem as follows:

$$\text{maximize} \quad U = E_P - \lambda\sigma_P$$

$$\text{subject to} \quad p_X X + p_Y Y = \overline{C} \tag{8}$$

$$\text{knowing} \quad E_P = X\,E(r_X) + Y\,E(r_Y)$$

$$\sigma_P = \sqrt{X^2\,\sigma^2(r_X) + Y^2\,\sigma^2(r_Y) + 2XY\,\rho(r_X,r_Y)\,\sigma(r_X)\,\sigma(r_Y)}$$

(a rewritten form of Equation 5),

where

$\sigma^2(r_X)$ and $\sigma^2(r_Y)$ are the variances of r_X and r_Y, respectively,

$\rho(r_X, r_Y)$ is the correlation between r_X and r^Y (a statistical measure of how r_X and r_Y vary together),

and all other terms are previously defined.

The statement in (8) now puts the problem in portfolio form. We can generate optimal solutions using the same methodology demonstrated in Figures 4, 5, and 6.

The function, $U = E_P - \lambda\sigma_P$, allows systematic planning for both force versatility and overall capability, provided we have the necessary data. (Where the data might come from is discussed in Section 5).

4. AN ILLUSTRATION

Let's suppose that we wish to procure fighter aircraft for the air-to-air mission, and that our choices are

X--relatively costly, large airframe, with all-weather capability, and

Y--relatively inexpensive, small airframe, with very limited weather capability.

Let's also suppose that only one variable in the collection θ affecting the future state of the world is of interest--average air-air visibility, $\overline{w}$.

Relative to almost any threat we would expect the effectiveness (r_X) of System X to increase, and the effectiveness (r_Y) of System Y to decrease as $\overline{w}$ decreases. Since we are also interested in resource constraints, we are particularly interested in the ratios of effectiveness to cost. We can, therefore, plot (r_X/p_X) and (r_Y/p_Y) as functions of $\overline{w}$, the average air-to-air visibility, as in Figure 7.

The effectiveness per dollar of system Y is quite low at zero visibility which increases with $\overline{w}$. On the other hand, System X is highly effective per dollar at zero visibility and becomes increasingly less effective as w increases. The two curves intersect at w_o. If we wish to attain a maximum level of effectiveness at some fixed cost, and if we know the value of w, then we will never engage in mixed procurement. If the known w is less than w_o, then

$$\frac{r_X}{p_X} > \frac{r_Y}{p_Y} \quad ,$$

and X is more cost-effective, and should be procured exclusively.

If $\overline{w} > w_o$, then System Y is the more cost-effective. If $\overline{w} = \overline{w}_o$, then we are indifferent. In no case are we better off with two systems in the inventory instead of just one. This point was made in Section 2.

However, the real-world problem is that we don't know what the average air-to-air visibility will be when the force is committed (probably because we don't know where the force will be committed). There is intelligence and climatological data available to give some notion of what w will be in the next war. We can summarize this information in terms of a probability distribution for w, as shown in Figure 8.

If we wish to have a versatile force we can choose X and Y so as to

$$\text{maximize } U = E_P - \lambda\sigma_P$$

$$\text{subject to } p_X X + p_Y Y = \overline{C} \ .$$

As in the section 3, this problem can be graphically analyzed as in Figure 9. Since r_X/p_X and r_Y/p_Y are obviously negative correlated, the efficient set bows strongly inward. Point A represents complete purchase of System Y, Point B all of System X; the curved segment AC is the efficient set and Point D represents the optimal solution.

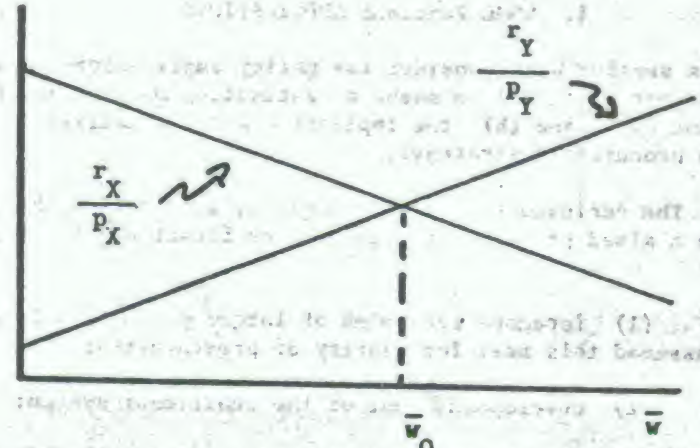

Figure 7.

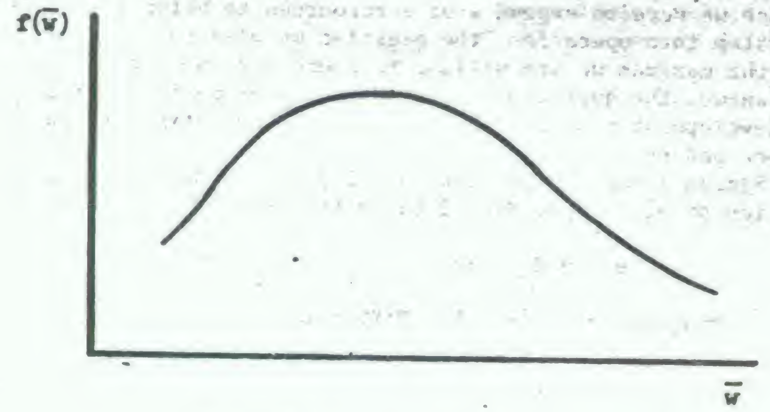

Figure 8.

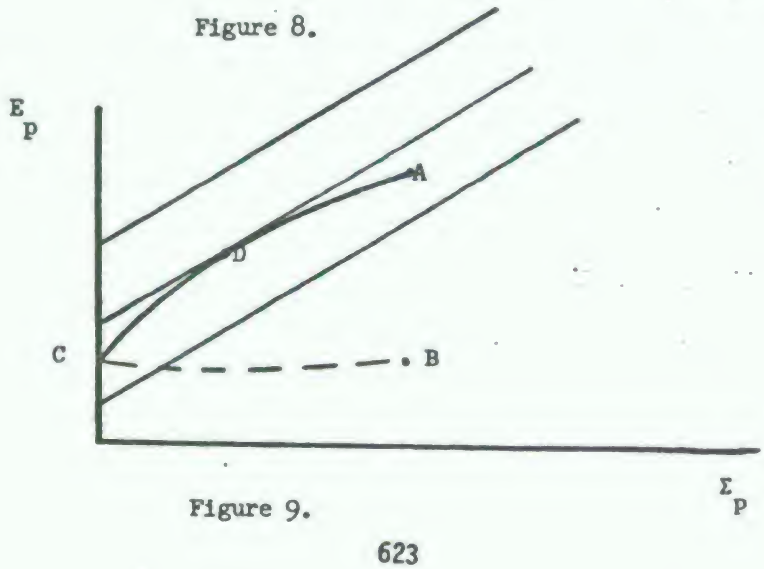

Figure 9.

5. SOME POSSIBLE APPLICATIONS

This section will consider two policy implications of the portfolio approach: (A) a means of estimating maximum acceptable development cost, and (B) the implications for intelligence information in procurement strategy.

A. The decision to develop, acquire, and operate the second system in a mixed procurement entails significant costs. Among them are:

(1) foregone economies of larger production lines; we have assumed this away for clarity of presentation;

(2) development cost of the additional system;

and (3) various overhead costs connected with life-cycle operations, including training and logistical support.

Since we have to expend source resources to bring any additional system into operation, the question we wish to consider is "What is the maximum we are willing to spend for the option?" To answer the question, we will expand our basic model to include development costs. We will consider tradeoffs between development and procurement.

If System X has already been developed, then the constrained optimization problem in Section 2 takes the form

$$\text{maximize } U = E_P - \lambda\sigma_P$$

$$\text{subject to } p_X X + p_Y Y + D(Y) = \overline{C}$$

$$\text{where } D(Y) = \begin{cases} 0 \text{ if } Y = 0 \\ \overline{D}(Y) \text{ if } Y > 0 \text{ ,} \end{cases}$$

and $\overline{D}(Y)$ is System Y's (assumed known) development cost.

The decision to expend known development costs on a system of known performance characteristics can be viewed as a choice between the two constraints

$$p_X X = \overline{C}$$

$Y = 0$, i.e., we do not have the privilege of purchasing System Y,

or $p_X X + p_Y Y = \overline{C} - \overline{D}(Y)$.

The first constraint leads to a solution at Point A in Figure 10a, where we spend all funds on System X and attain $U = U_1$. The second constraint is shown in Figure 10a as the curved segment BC. Since D(Y)has been expanded and therefore, there are fewer funds available for procurement. Hence, the amount of System X we can purchase with the remaining funds moves in to Point B. In this situation, the optimal procurement is represented by the Point D, attaining $U = U_2$. Since $U_2 > U_1$, the proper decision is to divert resources from procurement to development.

There are, however, limits to the amount that we'd be willing to spend. This is illustrated in Figure 10.b. In this case, the optimal solution (at D') from the second constraint, B'C', is clearly inferior to the solution at A. There is a critical value of D(Y) illustrated in Figure 10.c. at which we are equally well off with or without developing the new system. We can call this value $D(Y)_{max}$. The value $D(Y)_{max}$ may also be considered the worth of the new system in our weapons portfolio.

The value of $D(Y)_{max}$ depends upon the characteristics of System X, the characteristics of System Y, the degree of correlation in performance between the systems, and the decision-maker's degree of risk aversion.

Mathematically, we can state this as follows:

$$D(Y)_{max} \triangleq H(E(r_X), \sigma(r_X); \; E(r_Y), \sigma(r_Y); \; \rho(r_X, r_Y); \lambda)$$

where $E(r_X)$, $E(r_Y)$ is the average per unit effectiveness of X and Y respectively,

$\sigma(r_X)$, $\sigma(r_Y)$ is the standard deviation of the per unit effectiveness measures,

$\rho(r_X, r_Y)$ is the correlation coefficient of r_X and r_Y,

and λ is the previously defined measure of risk aversion.

If we take the characteristics of System X as given, we would expect to be willing to pay for developing a system that is highly capable [large $E(r_Y)$], or highly versatile [small $\sigma(r_Y)$]. However, we would also be interested in developing a system whose performance is negatively correlated with our existing system. In Figure 11.a., we show the case where a system slightly inferior to X, Y, whose performance correlates perfectly with System X would never be developed. Even with zero development costs, we would always choose to procure only System X. There is no reason to develop System Y.

In Figure 11.b., we show a decidedly inferior System Y_2, whose performance is highly negatively correlated with System X. System Y_2 is worth a significant development expenditure.

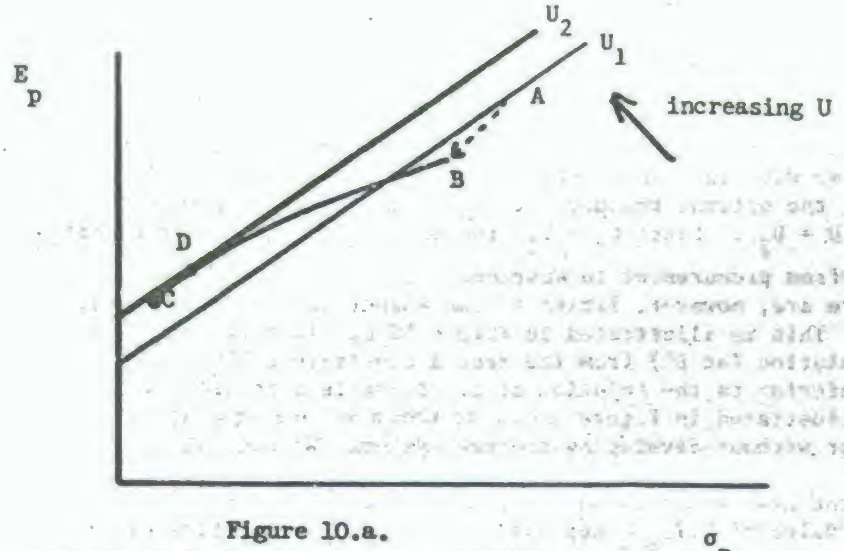

Figure 10.a.

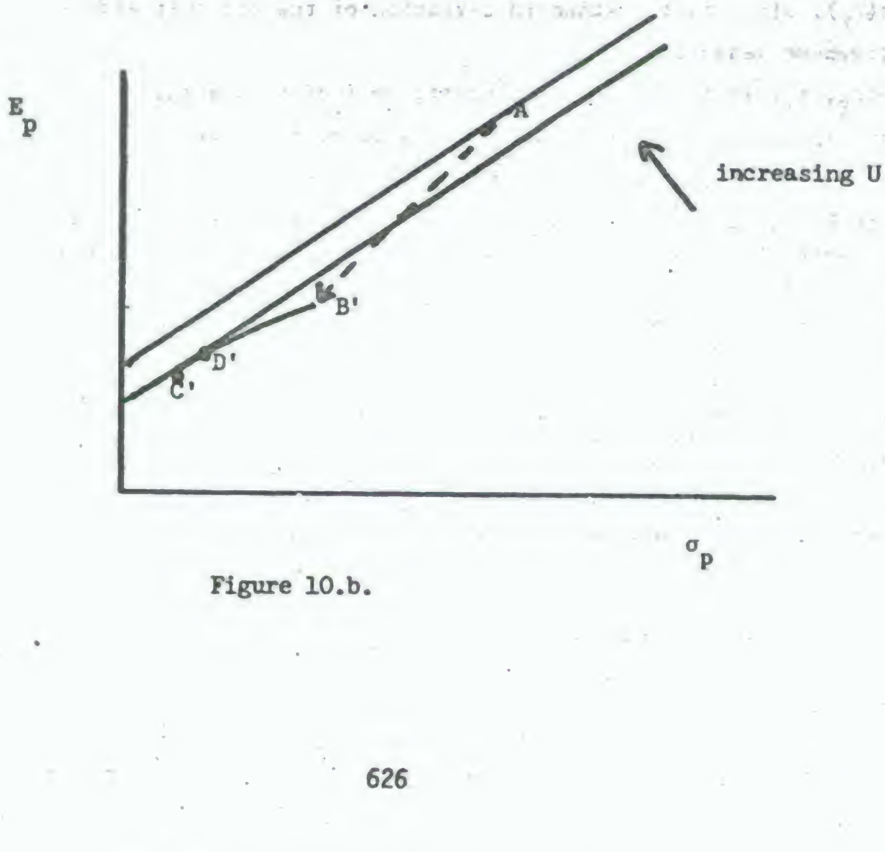

Figure 10.b.

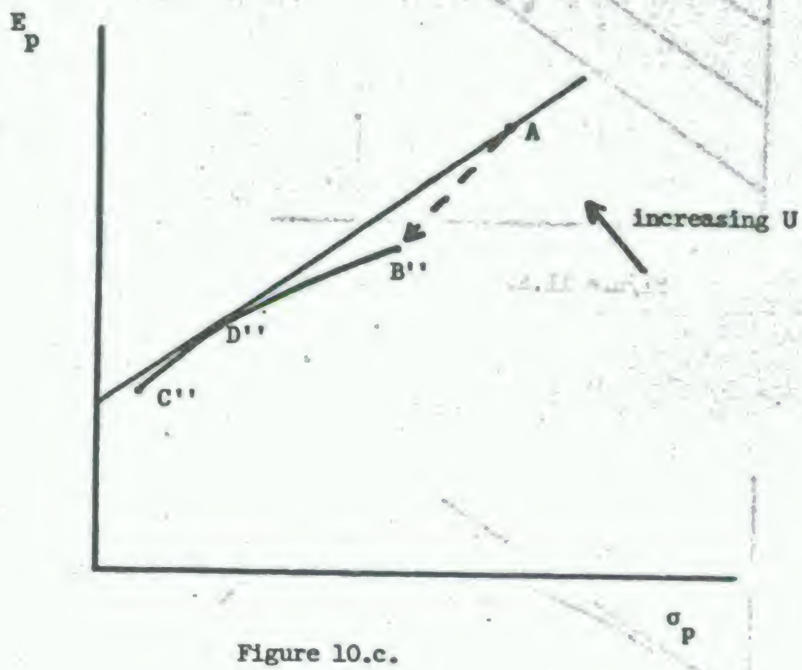

Figure 10.c.

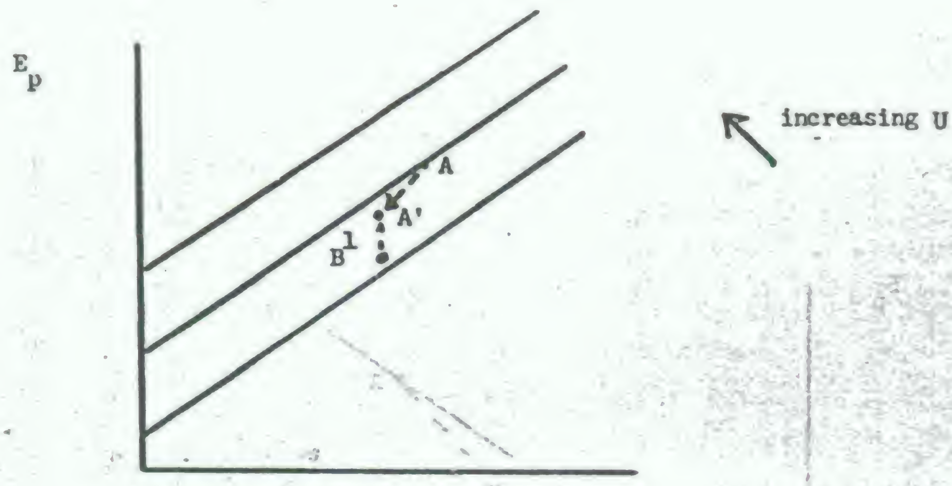

Figure 11.a.

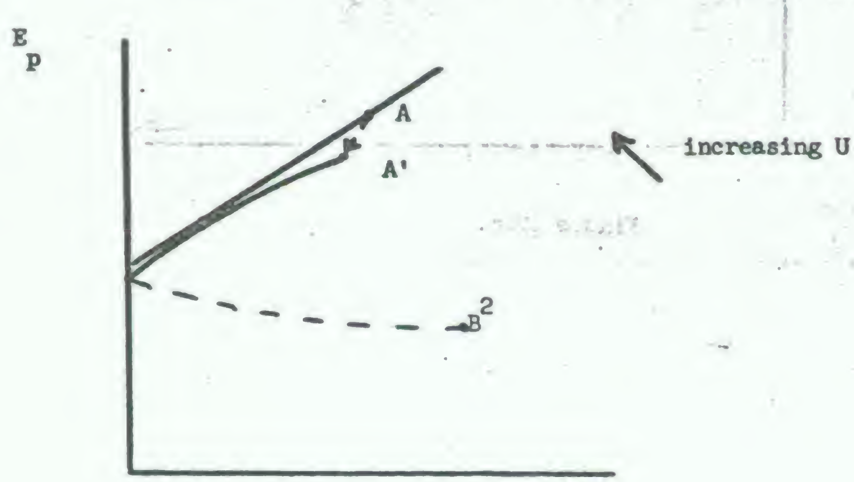

Figure 11.b.

In practice both development costs and performance characteristics are not known until development is over (and the funds already expended). However, it is still possible to estimate performance and costs at various points in the project. (It is theoretically possible to derive a joint subjective probability distribution of performance and costs). A key variable, however, is the performance correlation with existing systems. We know of no systematic effort to include this factor in our development project evaluation.

B. A very real question in response to our analysis is "Where do you get the numbers?" We intend to get our numbers (probability distributions, etc.) in the same general way that the portfolio theorist intends to get his. Portfolio Theory carefully differentiates between security analysis and portfolio analysis. Security analysis is an art which entails predictions about the range of future prospects of financial assets. Portfolio analysis is a method of solving a portfolio acquistion problem using the data generated by the securities analyst. (Sharpe, 1970) We propose to use the intelligence analyst as our counterpart to the portfolio theorist's security analyst.

This model therefore strongly implies that intelligence information must be the starting point for force planning. More importantly, it has major implications for the form and substance of those intelligence estimates. To mesh properly with the model, various perceived threats must be aggregated into groupings based upon operational similarity. For example, all scenarios positing a benign air superiority environment might be grouped. Groupings should have significant implications for systems performance requirements and, therefore, for hardware requirements.

Each threat category or grouping must then be assigned a likelihood of occurrence, generating a probability distribution for the overall threat. The development of an explicitly stated probability distribution is not currently a function of the Intelligence Community, but it is essential to employment of this Portfolio Theory model of flexibility planning and its logical extension, mixed procurement. Initially, providing such data will likely prove painful for professional Intelligence Officers, but the benefits derived from fully integrating Intelligence Estimates with procurement plans will more than compensate for the near-term discomfort--force planning can, in fact, begin with an explicit consideration of the threat, as planning philosophy always contended that it should.

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PROCUREMENT PLANNING AT THE

US ARMY ARMAMENT MATERIEL READINESS COMMAND

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In the interest of presenting a comprehensive review of the procurement planning processes at the US Army Armament Materiel Readiness Command, of necessity, I must begin by providing basic information about the Command mission, major functions, and special missions.

The assigned mission, simply stated, is as represented on this chart. The weapons and ammunition programs represent the greater part of the current annual program of approximately 3.1 billion dollars.

(Chart 1)

In addition to the commodity areas, ARRCOM has special mission assignments which significantly impact our procurement planning effort.

(Chart 2)

As previously stated, the assigned logistics management responsibility of the Command largely encompasses a wide range of materiel and equipment related primarily to the weapons and ammunition required to support the authorized force structure. This chart graphically illustrates the total weapons systems and other hardware items that ARRCOM manages.

(Chart 3)

With the basic information about ARRCOM behind us, I will quickly cover the policy guidance flow that impacts our procurement planning effort, recognizing that this guidance flow applies to most buying commands represented at this conference today.

As you know, the policy guidance develops gross requirements. The following chart depicts the factors which must be addressed to establish an actionable requirement for procurement. It must be recognized that as with every buying command, ARRCOM is not in a position to develop the total materiel requirements for assigned mission items even though requirements computation is a basic responsibility of the National Inventory Control Point (NICP) at ARRCOM. The final recommendations are developed by a committee of representatives from various organizations and project managers offices, and many tough decisions are necessary in the shaping of the final recommendation because all items must be accommodated within the program total dollars guidance provided. Once the buy recommendation becomes part of the applicable budget year estimate and the Department of the Army Procurement Annex, and apportionment is effected, the program is released to DA by OSD where it is released to ARRCOM through DARCOM.

(Chart 4)

That is not to say that from this point forward everything is going to fall into

a nice and easy procurement planning effort. The best laid plans are subject to change, and ARRCOM like every other buying command, does not escape the impact of changing customer requirements, late release of programs, program funding changes, cutbacks, stretchouts, etc., just to name a few.

The Army Materiel Program (AMP) and the Five Year Defense Program (FYDP) are basic planning documents utilized by ARRCOM to set the procurement planning processes in motion. One of the first jobs to be done is to break the end item/round of ammunition into its various procurable elements, compute the quantities required, and determine the separate and total cost involved. A typical component breakout for a weapons system/ammunition item is depicted on the next two charts (Charts 5 and 6). There may be as many as 55 separate procurable elements for a single round of ammunition, and an equal or greater number of procurable elements for a weapon end item.

(Chart 7)

ARRCOM's procurement planning process must address multiple factors to assure cost effective and efficient procurement of assigned materiel. A key document in the planning process is the Five Year Defense Plan (FYDP) which you all know provides current year plus the projected requirements for the subsequent four years. To this, of course, must be added other DOD and International Logistics customer actual and projected requirements.

Once the total requirement data is available and the breakout action is completed, it must be determined which requirements will be procured by other DOD components, what materiel will be procured commercially, and what materiel will be procured through our arsenal and ammunition plant production complex.

If the item is to be commercially procured, it must be determined how it will be effected: advertised, negotiated competitively or sole source or restricted to planned mobilization base producers pursuant to 10 USC 2304(a)(16) - Purchases in the Interest of National Defense or Industrial Mobilization.

If the determination is made that the materiel will be produced by the arsenal or ammunition production plant complex due to the unique situation that there is limited capability in the private sector of industry to produce a major part of ARRCOM's materiel requirements - and this is especially true with munitions items - a totally different set of planning factors come into play. All planning effort, in this instance, is influenced by the previously referenced production capability of the three Government-Owned Government-Operated (GOGO) arsenals and the twenty-six Government-Owned Contractor-Operator (GOCO) ammunition plants producing or capable of producing programmed weapons and munitions requirements.

A quick look at the arsenal production capability at this point, I feel, will be beneficial. Rock Island Arsenal is a proven producer of weapons and weapons components. Watervliet Arsenal produces large gun tubes, mortars, recoilless rifles, breech mechanisms, and repair parts. In the munitions area we have a combined industry and government situation. Ammunition propellants and explosives are manufactured in the Army ammunition plants with raw material, as available, obtained from industry. Ammunition metal parts (fuze, shell, and cartridge) are obtained from private industrial facilities, with hard-to-obtain and quantity lots not attractive to industry bidding being manufactured in the Army ammunition plants. The propellants and explosives and metal parts are funneled into the Army load, assembly, and pack (LAP) plants for assembly into complete rounds for delivery to the customer or inventory. The direction to maintain this production complex, predicated on the recognized need to maintain an industrial moblization base, retain technical skills, etc. in the event of a national emergency, is the "Arsenal Statute" which was originally enacted in 1920 as an amendment to the National Defense Act of 1916,

and subsequently revised and updated into its present version in 1965. The Act specifies, "The Secretary of the Army shall have supplies needed for the Department of the Army made in factories and arsenals owned by the United States, so far as those factories and arsenals can make those supplies on an economical basis."

I am sure you have noted at this point that because of this production complex, ARRCOM is unlike any other buying command. As we see it, we operate more like a prime contractor because our materiel requirements are fragmented between other DOD components, Government arsenals and ammunition plants, and private industry.

One of the planning considerations and an extremely critical one is the arsenal and ammunition plant workloading and production scheduling. In some cases, it is very simple as the capability to produce an item may be limited to a specific arsenal or plant which necessitates procuring the required item from that source. In most cases, especially in the munitions area, two or more plants may have the capability to produce certain items. Frequently, this combined capability exceeds the requirements; and in these cases, ARRCOM conducts an economic analysis to determine the low cost mix. This economic analysis is then subjected to an analysis of noneconomic factors such as mobilization and modernization requirements, skill retention, and personnel impact before a workloading decision is made. It can also be that insufficient active production capability is available to support a programmed requirement wherein the procedures cited above must be utilized to determine which facilities will be reactivated.

Paramount throughout the planning process relative to arsenal and plant workloading is the prime consideration of capability and lowest "out-of-pocket" cost to the Government. However, there are occasions when the requirement to maintain a viable production base may override the desire for an economical production rate and production will be stretched out to provide continuity of production. On the other hand, it may be determined to continue the production at the economical rate until the quantity is completed and let the facility go inactive. This will normally happen when there is no foreseeable follow-on buy.

Another significant planning consideration is the integration of procurement with Industrial Preparedness Planning. Previously, I referenced the use of 10 USC 2304(a)(16), negotiating authority for purchases in the interest of National Defense or Industrial Mobilization. ARRCOM is in all probability the largest user of negotiating authority (a)(16) because of our assigned logistics responsibility for weapons and munitions. As stated previously, there is no extensive capability in the private sector of industry to produce much of the required materiel, for the obvious reason that our weapons and munitions materiel requirements are non-commercial and negate industry's willingness to make the high dollar investment in facilities and equipment. It therefore behooves this Command, because of this limited industrial base, to sustain a plant, arsenal, or commercial producer of essential military supplies in the event of a national emergency. This is done through our industrial preparedness planning and our award of contracts to planned producers, utilizing the aforementioned authority.

I would like very quickly to touch on facility availability and how it may impact our planning efforts. It has happened, and I am sure it will happen again, that due to technological advances in the state of the art, ARRCOM is faced with the fact that the capability to produce the item, whether with industry or government, is nonexistent or partially existent. This situation would of course necessitate either the establishment of the production capability - installing the required production equipment in a new or existing facility which may necessitate planning effort four or five years in advance of the actual requirement - or the modernization and updating of the production equipment in the instance of a partially existent production line. Or it may be that increased

requirements are such that the production capability must be expanded, in which instance new facilities will be established and production contracts for the initial requirement will be executed.

Production lead time is especially critical in the procurement planning effort for weapons and munitions materiel due to the wide variance of production lead times applicable to the many separately procurable components. Plant and arsenal workloading and production scheduling, the placement of orders with other DOD components, and contracts with industry must be geared to the long lead time items to assure timely delivery of the many components for final assembly of the end item. This Command, on occasions in the past, because of production lead time factors has been subjected to limiting competition or justifying sole source procurement for items which normally would be fully competitive. This is a situation our planning process strives to avoid completely.

ARRCOM, like any other buying command, has utilized multi-year contracting to assure a steady flow of required materiel; awarded multiple contracts for the same item to assure sufficient quantities of required items are available; and also has recoursed to the issuance of solicitations in advance of the actual receipt of program funding to expedite contract award when the funding is actually secured.

The last of the procurement planning factors which I will discuss relates to material availability and how it adds dimension to our planning process. It should come as no surprise to you that within the weapons and munitions area there is a continuous need for special metals, forgings, castings, etc. which may or may not be readily available in the market place, or it may be that the requirement is insufficient to attract industry. When any one of the many circumstances relative to the availability of material is evidenced, our planning considerations immediately look to a series of possible remedies. Some of these remedies are as follows: can material substitution be made without creating technical/functional or reliability problems, are DO/DX ratings on contracts being appropriately utilized, are rated purchase orders being used (authorized controlled material orders), and are the specifications being reviewed to determine if they are unnecessarily restrictive?

Permit me to digress for a moment by citing a Command experience that is a bit unusual. In one particular situation a prior supplier had a large stockpile of long lead time material in his inventory which the Command knew could be utilized in the production of an urgently required item. Suffice it to say, the Command used this ready availability of the material and the urgent requirement to justify a sole source procurement with the resultant delivery of the required item well in advance of normal production time at favorable cost to the Government.

In closing, I would like to say that the complexity, criticality, and cost of ARRCOM assigned materiel coupled with those unique factors existent at the Command necessitate a viable, consistent, and well-coordinate planning effort to assure effective procurement of the assigned materiel.

CHART 1

MISSION

PROCURE WEAPONS AND AMMUNITION FOR DOD

AND INTERNATIONAL LOGISTICS CUSTOMERS.

CHART 2

UNIQUE ASPECTS OF ARRCOM PROCUREMENT PLANNING AND ACQUISITION

1. MANUFACTURING ARSENALS
2. ARMY AMMUNITION PLANTS

CHART 3

MATERIEL ASSIGNMENTS

WEAPONS SYSTEMS

- TOWED AND SELF PROPELLED ARTILLERY
- MORTARS AND RECOILLESS RIFLES
- ROCKET LAUNCHERS
- INDIVIDUAL AND CREW SERVED WEAPONS
- AIRCRAFT ARMAMENT

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- FIRE CONTROL SYSTEMS
- WEAPON MOUNTS & CONTROLS
- FEED MECHANISMS
- CONVENTIONAL AMMUNITION
- PYROTECHNICS
- NUCLEAR & SPECIAL WEAPONS
- CHEMICAL WEAPONS & EQUIPMENT
- PROPELLANT ACTUATED DEVICES
- COMMON TOOLS, SPECIAL TOOLS
- INDUSTRIAL PLANT EQUIPMENT
- AMMUNITION & INDUSTRIAL GAGES
- EOD SPECIAL TOOLS AND EQUIPMENT

CHART 4

GUIDANCE

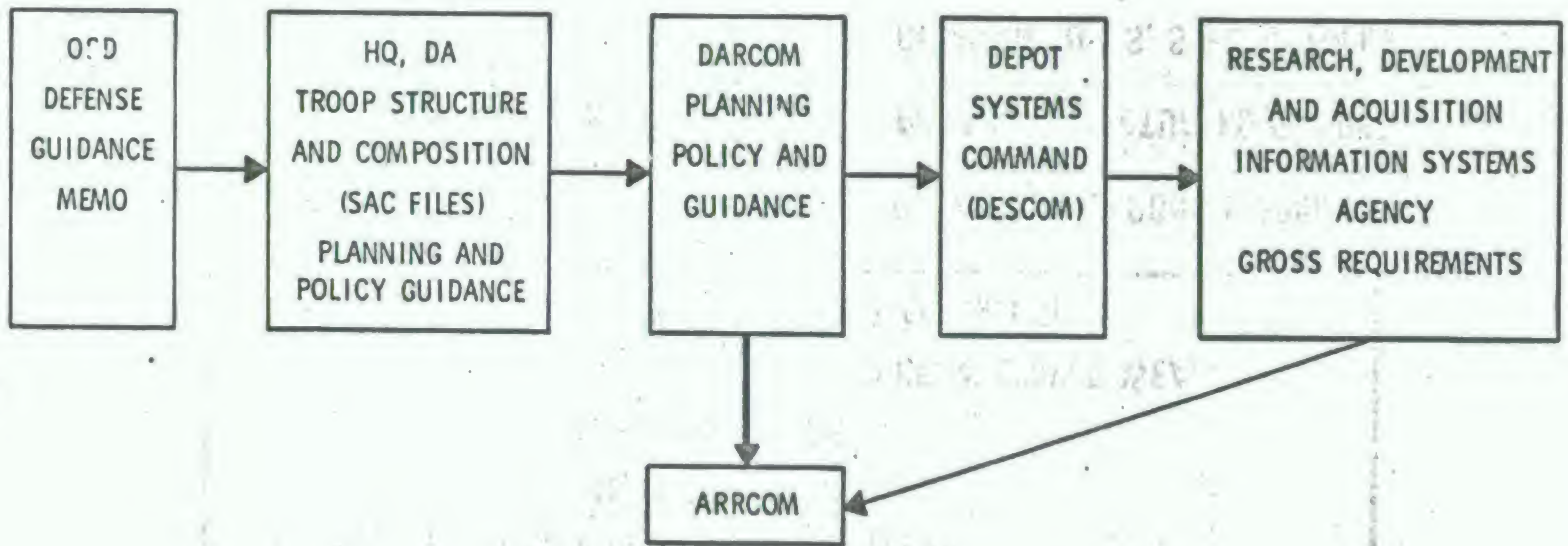


CHART 5

WEAPONS COMPONENT BREAKOUT

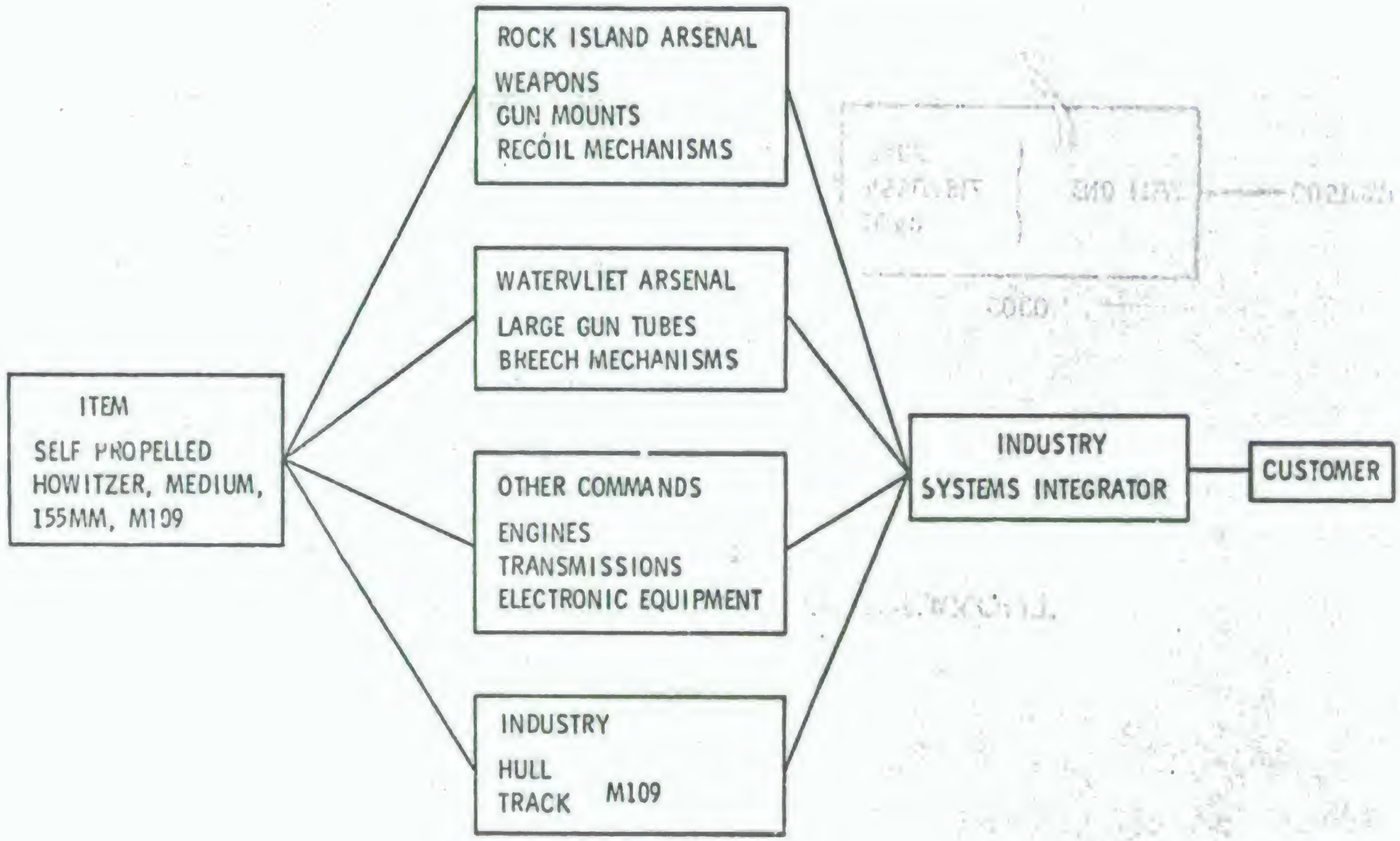


CHART 6

AMMUNITION COMPONENT BREAKOUT

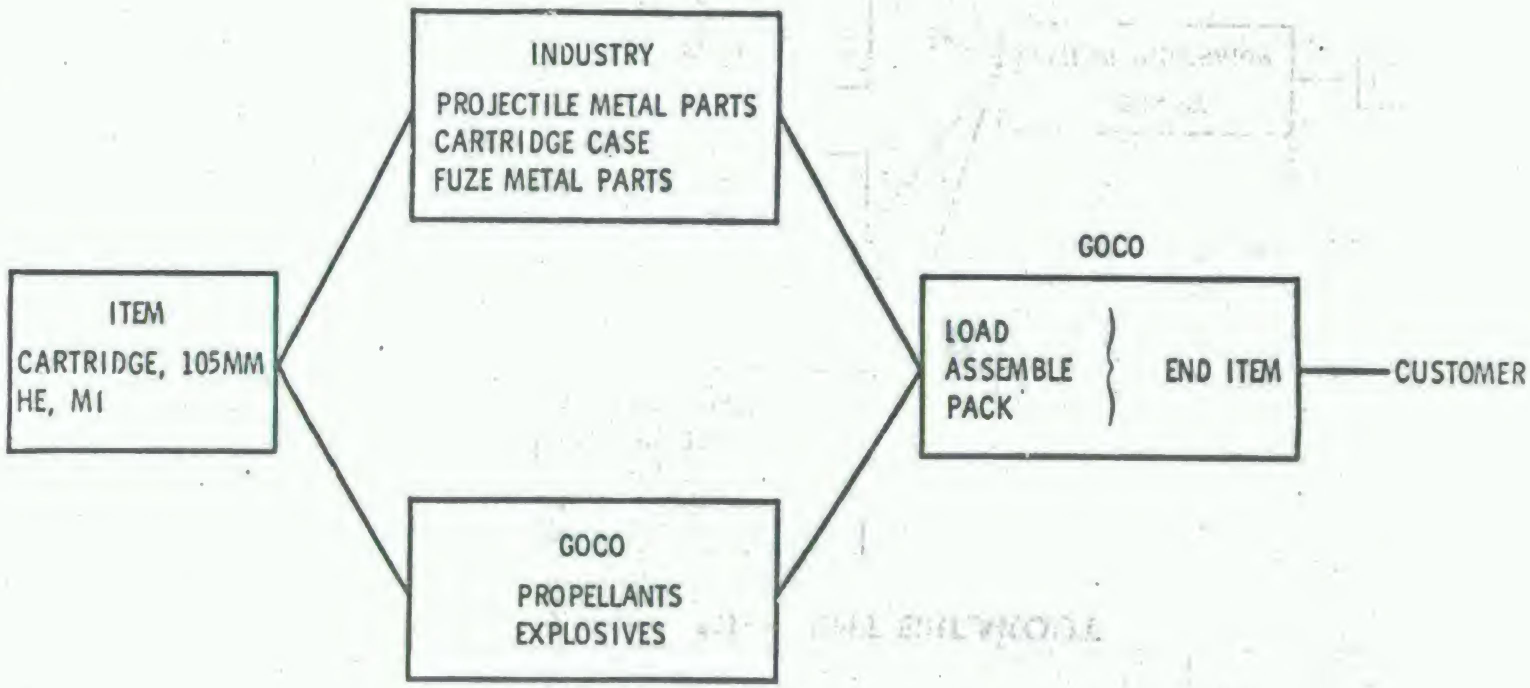
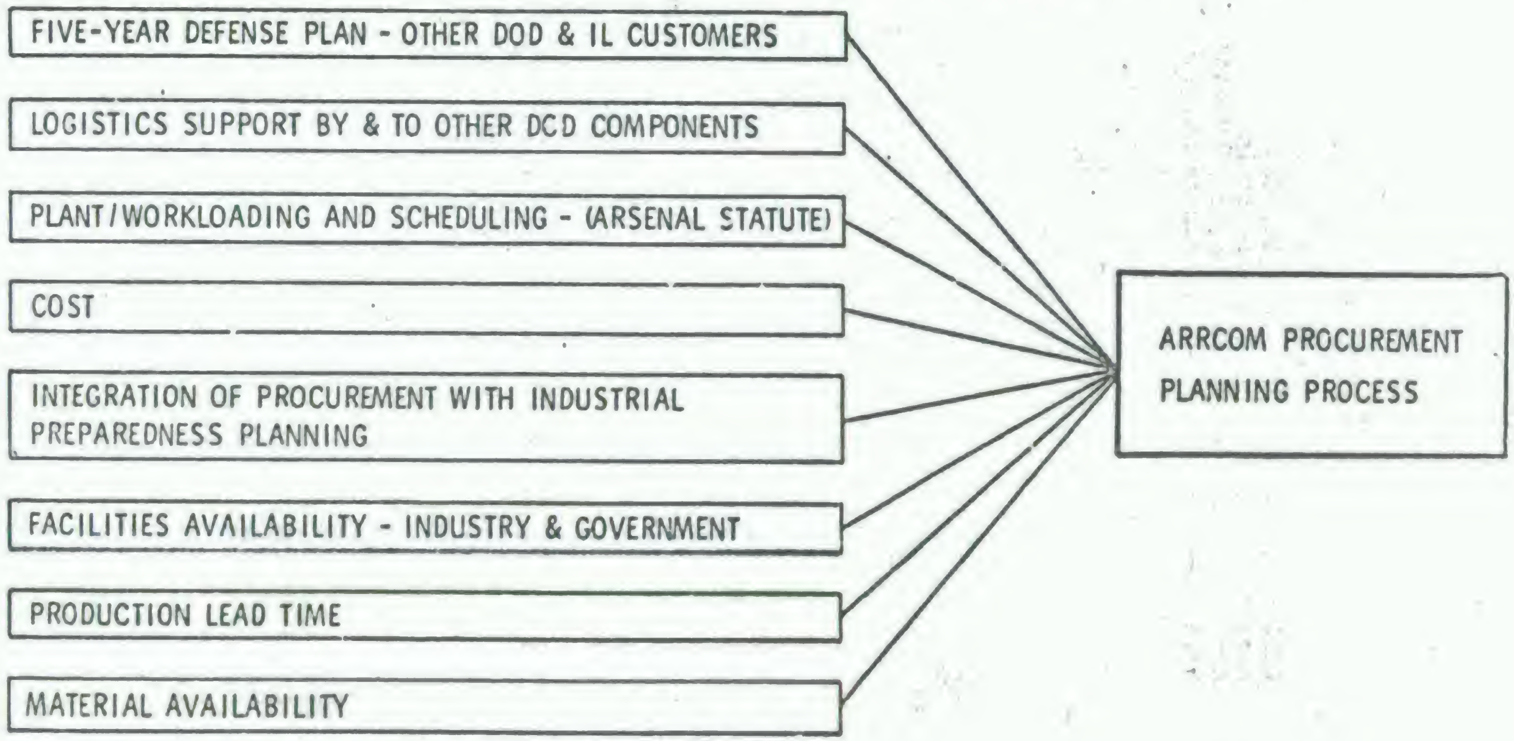


CHART 7

SIGNIFICANT FACTORS
ARRCOM PROCUREMENT PLANNING



IMPLEMENTATION OF OMB CIRCULAR

A-109 IN A WEAPON SYSTEM DEVELOPMENT

by

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FOREWORD

The ultimate goal of research is to produce results which eventually find their way into beneficial practice. In this vein, this paper discusses the "implementation end" of a landmark procurement research endeavor, that of the Commission on Government Procurement -- and the Commission's findings and recommendations as now embodied in the Office of Management and Budget Circular A-109, "Acquisition of Major Systems."

The discussions contained in this paper are based on the experience of the author as Business/Financial Manager, Shipboard Intermediate Range Combat System (SIRCS) Project, Naval Sea Systems Command. The paper does not reflect original research per se but rather provides a somewhat brief overview of how the SIRCS Project has applied the principles of OMB Circular A-109. The paper concludes with a number of personal observations on A-109 and the weapon system acquisition process which it has set out to reform. Although many of the observations that are made are the outgrowth of numerous discussions and debates with my colleagues over the meaning and effect of A-109, the opinions expressed herein are solely my own.

The foreword to this paper would not be complete without acknowledgement of those who have been key contributors to the process on which I am reporting. At the top of the list is the first and current SIRCS Project Manager, CDR A.S. Mobley, USN. CDR Mobley is a tireless and dedicated Naval Officer who has married a belief in the benefits of A-109 with an incessant drive to provide the surface Navy with a needed capability. Other key members of the SIRCS Team are too numerous to mention, but they represent an unusual assemblage of talented and hard-working Naval Officers, headquarters and laboratory civil servants, and contractors. To all of these men I am indebted for the opportunity to report on the fruits of their efforts. Acknowledgement would not be complete without recognizing those who provided the architecture and substance of the Report of the Commission on Government Procurement and OMB Circular A-109. Both documents contain sage guidance for those who engage in setting the course of weapon system developments.

Issuance of Office of Management and Budget Circular A-109 in May 1976 culminated a nearly 2-year joint Administration and Congressional effort to establish policy guidelines applicable to all Agencies engaged in developing or acquiring major systems. The Circular A-109 is a landmark effort which adds several new dimensions to the business of defining, funding and pursuing major programs in fulfillment of basic agency roles and missions. The development of the Navy Shipboard Intermediate Range Combat System (SIRCS), recognized as the first full-scale attempt to implement the A-109 policies, provides an excellent opportunity to evaluate a real-world application of the new acquisition policies. The following case study reviews the background and intent of A-109, traces the development of the SIRCS program from its inception, examines the SIRCS program structure relative to A-109 and finally provides some general conclusions in the form of "lessons learned" to date.

OVERVIEW ON A-109

In November 1969, Public Law 91-129 was passed creating a Commission on Government Procurement (COGP) for the purposes of studying and recommending to Congress methods to promote the economy, efficiency, and effectiveness of procurement by the Executive Branch of the Federal Government. The Commission on Government Procurement was made up of Congressmen, Senators, and representatives from the private sector and the Government. Almost 500 people worked on the Commission staff conducting the study, and over 150,000 pages of feeder reports were submitted by the working groups to the Commission. The acknowledged reputation of several of the Commissioners and exhaustive research and analytical effort conducted by the Commission staff combined to cause generation and issuance of a 5-volume report that has set in motion profound and needed change to the government procurement process.

The U.S. Senate Committee on Government Operations of the 94th Congress, created a Sub-committee on Federal Spending Practices, Efficiency, and Open Government to provide a Senate focal point for the review of Federal spending practices, particularly Federal procurement. A major part of this review was directed toward the report of the COGP, in particular those recommendations made by the Commission concerning the controversial area of acquiring major systems. The report includes 12 specific recommendations, which in summary attempt to establish effective control over systems acquisition programs, define organizational roles and levels of responsibility, and assure decision makers have access to the information necessary to make key decisions. The

Federal Spending Practices, Efficiency, and Open Government Subcommittee is continuing to investigate the recommendations of the Commission and to develop a legislative program to implement the needed changes.

In 1974, the Congress established the Office of Federal Procurement Policy (OFPP) in the Office of Management and Budget (OMB) to provide overall direction of procurement policies, regulations, procedures for executive agencies. In its first major policy action, the OFPP issued OMB Circular A-109 prescribing how major systems will be acquired by all Executive Branch agencies. This new policy was consistent with the unanimous recommendations of the COGP concerning the establishment of needs and goals for new programs, exploration of alternatives, choosing a preferred system, implementing a system, and organization, management and personnel.

Circular A-109 does not offer a "cookbook" approach to system acquisition. The circular recognizes that each major system acquisition program is unique in terms of time, cost, technology, management and contracting approach. Despite these differences, the basic process and the principal activities in the process are common to all programs. It is these basic elements to which A-109 addresses itself.

The first key decision in the acquisition process is the agreement and approval of the mission need statement. The approach of A-109 is to have the mission needs and goals evaluated and reconciled - - - in the context of the overall agency mission, resources and priorities - - - at the top management level and at the outset of the acquisition. A-109 outlines an integrated systematic approach for establishing mission goals in terms of capability desired, time and operating constraints, value or worth of meeting the need and relative priority of the need within the agency, thus bringing together the budget and procurement aspects of the process.

Beginning in FY-79, each agency will be required by law to submit budget information in accordance with assigned agency missions, and to relate agency programs to these missions. This requirement is part of the Congressional Budget Act of 1974 and is reiterated in A-109 as the basis of establishing an earlier and more meaningful communication with Congress in the budget process. The objective is to have Congressional level issues regarding needs resolved early in the major system acquisition process, before the commitment of major resources and selection of solutions. Congress can thus withdraw from the annual process of detailed review of system solutions and program acquisition data and can focus on broader questions of agency roles and missions - - - a role more appropriate to Congress' fundamental purpose.

Another major emphasis of A-109 is the early initiation of competition and maintenance of competition in the acquisition process. Competition in the sense of A-109 is not merely the solicitation and review of competitive proposals, but rather the use of competition during the development, demonstration, and, if economically beneficial to do so, throughout the complete acquisition process. This entails the actual parallel development of several viable total-system alternatives. The higher cost of maintaining this competition amounts to insurance against the possibility that premature selection of an alternative may later prove to be unsound or unaffordable.

ORGANIZATIONAL CHANGES CALLED FOR UNDER A-109

The improvements in the system acquisition process called for by A-109 will not come about without concurrent changes and redefinition of the roles of the various activities and organizations involved. Table 1 presents a very simplified, perhaps oversimplified comparison of the A-109 roles vis-a-vis the "traditional" roles.

TABLE 1: ORGANIZATIONAL ROLES UNDER A-109

	TRADITIONAL ROLE	A-109 ROLE
CONGRESS	DETAILED REVIEW OF INDIVIDUAL BUDGET LINE ITEMS	REVIEW BUDGET REQUESTS ON MISSION NEED BASIS
OSD	APPROVAL/DISAPPROVAL OF SPECIFIC PROGRAMS	APPROVAL OF MISSION NEED
SERVICE	HARDWARE ADVOCATE	IDENTIFY AND ARTICULATE MISSION DEFICIENCIES
LABORATORIES	TECHNOLOGY/HARDWARE ADVOCATE	MAINTAIN TECHNOLOGY BASE; PARTICIPATE IN EVALUATION OF SYSTEM ALTERNATIVES
INDUSTRY	PROVIDER OF RESOURCES TO BUILD HARDWARE IN RESPONSE TO GOV'T SPEC	RESPOND WITH SYSTEM ALTERNATIVES (SOME OF WHICH ARE EVENTUALLY DEVELOPED AND PRODUCED)

As indicated earlier, the Congressional role shifts to the higher order function of authorization and appropriation of budget requests on an agency need basis. Similarly, OSD is assigned a role to review and approve basic mission needs as articulated by the individual services, rather than having to analyze the specific hardware solutions proposed to meet the need. These changes reflect the desire to increase understanding within the Congress and at the higher agency levels, of the threat, mission deficiencies, program goals and ultimate purpose of the system to be acquired.

The roles of the Government laboratories and the industrial participants is also affected by A-109 with respect to the manner in which systems are defined and produced. Whereas the laboratories traditionally become involved in defining hardware solutions to be produced by industry, the laboratories are now given a role better suited to their charter responsibilities and capabilities - - - developing and maintaining a technology base. Government laboratories are assigned the primary responsibility to maintain the agency's technology base through sponsorship of technologies in support of the agency's missions, thereby ensuring a linkage between R&D efforts and the agency goals. Industry is asked to respond with proposed system solutions to a broad statement of mission need. Thus, the private sector is provided with a greatly expanded opportunity to engage in an imaginative search for solutions as opposed to being constrained to respond to rigid hardware specifications. The responses of several competing industry firms represent alternative system design concepts to be evaluated (along with others that may have been developed internally) to identify those that satisfy the approved mission need. The newly defined roles provide the greatest effective utilization of both the public and private sectors involved in the process.

OVERVIEW ON SIRCS

In 1974, the Navy initiated an effort to develop a new, second-generation shipboard system to provide a balanced intermediate range offensive strike and self-defense capability. On-going efforts were critically reviewed to determine the extent to which they should be continued, curtailed or accelerated, - - - resulting in a decision to merge the on-going Advanced Anti-Ship Missile Defense (ASMD) System and the Lightweight Intermediate Caliber Gun System developments. These concurrent efforts had overlapping mission requirements, in part addressed the same threat, and had similar development, completion and fleet introduction dates. It was concluded that to proceed with the two efforts independently would have resulted in duplicative developments.

A number of lesser developmental efforts were also amalgamated and combined with the restructured effort to address a multi-dimensional threat in a more logical, integrated fashion.

A revised statement of operational requirements, combining both ASMD and surface warfare mission needs was issued in May 1975 for a balanced intermediate range combat system capable of defending against the projected anti-ship missile threat as well as engaging surface threat and shore targets. The new effort was called the Shipboard Intermediate Range Combat System (SIRCS).

The period from mid-1974 to the present, covering SIRCS program origination and conceptual formulation activity, parallels the period during which substantial change occurred in areas of administration policy affecting the development and acquisition of major systems. Although such policy changes did not culminate in formally promulgated documents (e.g. Circular A-109) until 1976 - - well after initial SIRCS planning commenced - - SIRCS program planning and execution actions were patterned from the outset to follow policy direction that the Navy knew to be emerging.

SIRCS ACQUISITION STRATEGY

The SIRCS program was initiated with a 3-page statement of an operational requirement (mission need) for a system that could provide a total, detection through engagement capability, modularly adaptable to various ships according to individual size, mission and capability constraints. The operational requirement (OR) identified the nature of the threat and the desired performance, reliability and cost goals for the system. This concise statement of requirements was tailor-made for the purpose of communicating to industry a very broad, but bounded, problem to which industry could respond with independently conceived concepts. The OR did not specify a hardware requirement nor indicate any preference for a postulated technical or conceptual approach, except to emphasize that new developments were neither required or desired unless significant benefits would result. This broad initial mission need statement provided industry with the flexibility to perform trade-offs and propose solutions, based upon their own analysis of the problem. The Navy challenge to industry generated seven substantive industry responses, resulting in award of three separate, funded, cost-type concept formulation study contracts in May 1976 to McDonnell Douglas, Raytheon and RCA. The 9-month contracts committed each contractor to develop an independent concept for a totally integrated system based upon his analysis of the requirements, existing developmental efforts and available or emerging technology.

Having effectively established the industry competition early in the conceptual phase, the SIRCS acquisition strategy is designed to sustain competition as long as it is beneficial. The Navy will continue to make incremental investments in the most promising alternatives as the number of options is reduced. Throughout the development process, the competition serves to "keep the contractors honest" in what they proposed or include in their concepts. The

decision to use existing, modified or new developments is balanced between each contractor's evaluation of the advantages (performance, cost, reliability, etc.) and the competitive incentive toward economy in the design activities.

A very important aspect of defining the requirements as implemented in the SIRCS program is the "bounding of the problem". This involved providing three specific types of additional information to the contractors in order that they could better understand the problem from a Navy perspective. First, the Navy provided an expansion of the requirements (Operational Requirements Expansion) in terms of quantitative goals and thresholds; in effect providing a region within which the contractors could perform their tradeoffs. Second, baseline information was compiled and provided so that each contractor could respond to the requirements under a common set of defined constraints; such as, threat and target parameters, operating environment (man-made and natural), configuration of the future fleet, characteristics of existing ships and weapon systems, and resources available for Navy test and evaluation. Third, the Navy provided a Cost Analysis Guide to articulate as clearly as possible, detailed cost elements and definitions, ground rules and assumptions for cost estimating, and formats for presentation of cost analysis data. The total of the data furnished in a 7-volume Government furnished information (GFI) package was supplemented by oral briefings on technology base programs, and the establishment of a GFI data center containing over 2,000 technical documents, study reports and system manuals, all of which was made available to each competing contractor.

Having thus defined and bounded the problem for the competitive concept study contractors, the Navy solicited industry responses to a rather simple statement of work (SOW). Essentially, the SOW reads as follows:

> ...undertake an indepth study...to develop a system concept to meet the Operational Requirement for (SIRCS) and...develop a formal proposal to validate this system concept.

Although the SOW appears on the surface to be overly general, it is consistent with the generalized statement of mission need in the Operational Requirement. Initially there was some feedback from industry indicating a preference for more specific guidance. However, once the study contracts commenced, there was no question that contractors were prepared to take a total system approach to this broadly defined total problem. The Navy very specifically outlined the required content of a 2,035 page study report as the primary deliverable under the contract. The contractors were required to define not only the proposed total system concept, but also to identify the analyses and trade-offs that led to the concept and fully justify their decision processes. The initial

evaluation of the concept reports indicates that all contractors were responsive to the requirements and that the concept formulation phase was successful.

Three other key elements of the SIRCS solicitation based upon A-109 policies are recognized as having contributed to the success of the SIRCS concept formulation. In keeping with the A-109 policy, draft copies of the solicitation documentation was distributed to industry for comment. Many substantative comments were received and incorporated. Another feature of the solicitation was the identification to the contractors of the criteria that would be used to evaluate the proposed approach to the study as well as the criteria for evaluation of the resulting concepts. This also served as a method of conveying to industry the relative importance that the Navy ascribed to performance, cost and risk elements of the contractor's concepts. Finally, the Navy required as a deliverable at the conclusion of the concept phase (and plans to require at the conclusion of each subsequent program phase) a proposal for the next phase. The contractor concepts deemed appropriate for further development can thereby be continued through a series of carefully planned incremental investments by the Navy.

SYSTEM AFFORDABILITY

Balancing the degree of technological advancement to yield a given operational capability at an affordable cost represents a significant challenge for any modern weapon system development. The problems involved in such balancing are particularly acute for a system as multi-dimensional and operationally complex as is the case for SIRCS. The challenge is compounded even further due to the physical constraint of SIRCS being a point defense vice an inter-ship or force coordination type weapon system. For a point defense system such as SIRCS there is an inherent conflict (trade-off) between achieving cost-effectiveness for a given platform versus that for a total fleet. For instance, a relatively minor but needed increment of system effectiveness for each SIRCS suite may multiplicatively drive total program cost to a level which is unaffordable in quantity.

Recognizing the general tendencies toward high cost system alternatives, plus the criticality of concept formulation trade-offs to the achievement of a low cost design, the SIRCS Project Office established a rigorous cost discipline at the start of concept formulation. Beginning with the Operational Requirement (OR), acquisition cost goals were established on the basis of 10% of ship replacement cost or $10 million. Although such a cost goal structure was crude it provided a convenient sliding scale establishing upper cost limits for various configurations of SIRCS to meet differing ship mission requirements. When aggregated, ship platform cost goals for various SIRCS configurations provided concept formulation contractors with a cost region within which alternative concepts could be explored.

Although initial SIRCS cost goals did not encompass total life cycle cost (LCC), concept formulation contractors were challenged to seek design concepts which minimized life cycle cost. A number of facets of the procurement approach created this emphasis. First, the Operational Requirement firmly asserted emphasis upon reduced manpower requirements, in addition to delineation of acquisition cost goals. Second, an Operational Requirements Expansion provided the following direction regarding life cycle cost: "Minimization of life-cycle cost should be treated as a top-level criterion in selecting among design/system options..." The realism of this life cycle cost objective was established by virtue of the flexibility contained in the functional performance requirements given to contractors. These performance requirements were described in terms of mission vice equipment parameters. Performance values were stated as goals and thresholds, thus providing an interval within which trade-offs to minimize life cycle cost could be performed. To add specificity to this policy guidance on cost, the Cost Analysis Guide enumerated and defined 79 life cycle cost elements to be used as a basis for all contractor-generated system cost estimates. In addition to this standard cost element structure, costing ground rules, assumptions, and output formats were provided in the Cost Analysis Guide.

The most important reflection of the Navy's resolve to achieve an affordable design for SIRCS was the language of the evaluation criteria for selection of validation phase contractors. The selection criteria, which was part of the concept formulation contracts, contained the following statement: "System Military Worth and System Cost are of equal importance...". System Cost was described in the evaluation criteria as:

> System Cost - The purpose of this element is to evaluate the total life cycle cost to the Navy of acquiring and operating the system proposed by the contractor.

In the Validation and Demonstration Phase, design to cost goals are to be established for both life cycle cost and unit production cost. A series of LCC goals will be established for generic ship suites, e.g. high value, major combatant, and other. Production cost goals will be established for significant hardware elements, e.g. the SIRCS weapons, surveillance and tracking subsystem, command and control subsystem, etc. This structure will provide competing prime contractors with some flexibility to continue to optimize their design with respect to LCC while giving the Navy a measure of control over unit production cost. Cost goals are to be made a part of the SIRCS specification for the validation phase, with both cost and performance parameters specified in a manner to give contractors sufficient latitude for design iteration while simultaneously validating the high risk aspects of SIRCS.

POTENTIAL PROBLEM AREAS UNDER A-109

A weapon system development represents an environment saturated with problems. If the promises of A-109 come to pass many such problems will be eliminated. However, with any new complex policy, implementation poses new sets of problems which if not recognized can serve to erode what would otherwise be significant and important change. The following problem areas are not exhaustive, but are representative of significant "pitfall" areas for A-109 implementation efforts.

PRESSURES TO MAKE PREMATURE CHOICE AMONG ALTERNATIVES

Premature weapon system choice is an area that the Commission on Government Procurement singled-out for reform. The Commission's report succinctly stated the root of the problem:

> To explore different system concepts and introduce competitive development requires R&D money of a scale usually not made available until a decision has been reached that a given system approach should be pursued, something of a paradox.[1]

Circular A-109 does not solve this problem and may in fact heighten the pressure for an early choice or choices. The reason is that under A-109 it is difficult to avoid a fairly secretive and continuous source selection process from the time the first RFP goes out until the competition has been narrowed to a single developer or producer. This is particularly true during concept formulation, when inadvertent slips of information can precipitate technical transfusion of paper design features. This semi-cloak of secrecy impedes "selling" of the program and the commitment of significant R&D funds. Beyond this, there is in most of us a management ethic which creates a propensity to make decisions. To prolong choice can be perceived as a lack of management discipline and an impediment to schedule progress. Hence, a program manager under A-109 may feel significant pressure to pursue a rapid winnowing of concepts and contractors to the detriment of the longer term benefits of the A-109 approach.

TIME AND RESOURCES SPENT IN FRONT-END SOURCE SELECTIONS

A-109 encourages a broad base of alternate concepts and contractors during the Exploration of Alternatives Phase (Concept Formulation). The use of short-term low dollar value contracts are meant to provide flexibility for pursuing an unconstrained and iterative search for the most promising alternatives

1 Report of the Commission on Government Procurement, Vol. 2, Part C, p. 89.

to meet a mission need. Such contracting flexibility would mean, for example, that contractors/concepts would be dropped and others continued based on periodic new information stemming from a series of concept formulation and exploratory contracts. Such an approach makes a great deal of sense, but does not appear to recognize the time and resources which would be claimed under the traditional Department of Defense (DOD) approach to source selection.

One could argue that A-109 series contracting, as described above, does not entail source selection per se. Prior to A-109 the concept formulation phase frequently entailed low dollar value contracts with potential developers. A source selection process was avoided because a validation phase contractor or contractors were normally selected as a result of a new solicitation, with the basis of the solicitation being developed during the concept formulation phase through the melding of various inputs from both government and industry sources. The approach of A-109, however, is to avoid such melding and resolicitation, and to instead, substitute parallel competition. Hence, instead of periodic source selections, A-109 tends to create a continuous source selection process, particularly during the front-end Exploration of Alternatives Phase. As a consequence, each decision to continue a competitor, and more importantly, to drop a contractor becomes a source selection decision. For major programs such decisions are of course of major importance to each of the industrial participants. Thus, a dilemma is created by the A-109 parallel competition approach. For major programs, where exploration of alternative concepts should normally be pursued to the maximum extent, there may be a counter influence to minimize such exploration because of the time, expense, and trouble associated with the source selection machinery which DOD policy would dictate must be established.

The answer to the above problem relates to the manner in which the current DOD source selection policies are carried out. It is beyond the scope of this paper to engage in a discussion of existing DOD source selection practices. However, the problem discussed above warrants scrutiny of source selection conventions with a view toward creation of a more streamlined, less formal, and less time-consuming process, and one which can truly accommodate the unfettered exploration of concepts from contractual sources as called for by A-109.

HIGH COST OF EXPLORING ALTERNATIVE CONCEPTS

Developing suitable information for a spectrum of alternatives to fulfill a major system deficiency is expensive. Without adequate budgetary support on the "front-end" the base of alternative concepts will probably have to be artifically limited.

This was the case in the SIRCS Program, with a lack of budgetary support forcing a limit in the number of concept study contracts which could be awarded. The problem, however, is even more basic than simply a lack of funding for study contracts.

Under A-109, a vastly expanded scope of activites is to be conducted in defining requirements and exploring alternatives. This new scope of effort in initiating programs will require additional resources not only on the government side, but there are also implications for the manner and level at which corporate independent research and development (IR&D) funds are expended. One can speculate that as DOD becomes more accustomed to the A-109 process that RDT&E resources will become more properly allocated as a result of DSARC Zero decisions. Similarly, one could expect that corporate IR&D monies and other internal funds will become more appropriately channeled in response to documented statements of mission need emanating from the Services. Notwithstanding these predictions, the point is that A-109 requires an expanded effort for early program activities. Funding for this new requirement dictates an appropriate awareness on the part of government and industry officials in the conduct of R&D resource allocation decisions.

ESTABLISHING COST BOUNDS
PRIOR TO HARDWARE DEFINITION

A-109 requires that program (not unit) cost objectives be contained in the initial mission need solicitation. For the SIRCS Program, a General Accounting Office study criticized the approach of assigning initial design to cost objectives at the platform level vice the total program level. Although A-109 is theoretically correct in the approach of using total program cost objectives, practical problems make full implementation difficult if not meaningless. For instance, for most major system programs, with the exception of space and satellite systems, the number of units produced is the most significant determinate of total program cost. Additionally, difficulties arise in describing the mission capability that is required in terms other than those which, de facto, tend to describe either the unit, the platform from which the unit is to be operated, or the geographical limits of the unit's operation. For SIRCS, the mission need that SIRCS was responding to was described in terms of a system operating within a ship to provide the ship with a needed capability. Trade-offs and system alternatives were thus constrained to the boundaries of the single ship. It would have been illogical for the SIRCS Program to have set a cost objective for a total program without one-to-one correspondence between such an objective and the mission need to be fulfilled.

Notwithstanding the express direction in A-109, the most meaningful way to address the problem of setting initial cost objectives is to juxtapose the cost objectives with the unit for

which the mission deficiency is described. The cost objective could then derive from a total program affordability projection to be divided by an assumed multiple relating to the unit for which the mission deficiency is described. For example, affordability projections have been made in the SIRCS Program. In establishing and assessing design to cost goals, this total affordability region is divided by a presumed number of ships to be outfitted thus giving an upper cost boundary for a SIRCS suite.

The key to the type of approach described above for setting cost objectives is in making affordability projections. Although for the SIRCS Program such projections have represented extrapolations of budgetary data, affordability should be based on a willingness to pay for the required capability. In practice, the allocation of resources under the Planning, Programming, and Budgeting System (PPBS) does not always operate on such a higher order basis. However, with the full implementation of A-109 and mission-oriented budgeting, as is required for FY 1979, allocation of resources based on a willingness to pay for a capability may someday become a routine reality. Indeed, such a reorientation is probably the key challenge in the implementation of A-109 and in bringing about an integration between the DSARC and PPBS processes.

INITIAL CONCLUSIONS ON A-109
AS A WEAPON SYSTEM DEVELOPMENT APPROACH

Experience in the SIRCS Program has given rise to several important tentative conclusions regarding the long term benefits of A-109:

1. Improved linkage of resource inputs and program needs
2. Improved atmosphere for innovation
3. Reduction of suboptimization potential
4. Improved system engineering discipline
5. Reduced development lead time

Through definition of requirements in terms of mission need, the SIRCS Program has insured that development dollars expended will be linked to a valid fleet requirement. Similarly, the Program has effectively insulated itself from the pressures of the "solution looking for a problem" syndrome. As a result of the January 1977 revision to DODD 5000.1, an important step has been taken to institutionalize such advancement in the resource allocation process. This revision, which included a provision for a Mission Element Need Statement (MENS) as the basis for program origination approval, should serve as a key instrument for improved linkage between resource inputs and service program needs.

The SIRCS Program has enjoyed an atmosphere of inventiveness and problem solving fostered by industrial competition and the promise of significant future business. From this atmosphere have emerged weapon system concepts reflecting an objective balance between new and existing technologies, and across cost, performance, and risk dimensions. Certain features of these system concepts are innovative. Other acquisition approaches may have achieved similar results. However, unquestionably programs following A-109 create an atmosphere which encourages a high incidence of aggressive and innovative problem solving.

Defining requirements in terms of a total need forces total system solutions. Trade-off opportunities that might not be obvious for a subsystem development suddenly become manifest and imperative when solving the total system problem. The potential pay-off of defining total systems is more cost-effective military systems through avoidance of inbalances in subsystem designs.

Perhaps the biggest pay-off which SIRCS has enjoyed under A-109 is the disciplined system engineering process that industry program management teams have applied to a complex systems problem. These industry teams have had at their disposal data, information channels, and the necessary tools to engage in a timely and unfettered rational trade-off and sequential decision process. The in-house Navy bureaucracy, with its highly differentiated headquarters and laboratory organizations, would severely hamper such a streamlined and rational system engineering process. Hence, by going to industry for concept formulation, a system engineering resource is acquired that would be very difficult if not impossible to engender within the Navy.

Several features of A-109 combine to offer promise of a reduction in development lead time. Under A-109, proposals for the next program phase are received as contract deliverables. This forces advanced planning and eliminates the need for generation of new solicitations. Parallel competition provides schedule insurance in the form of fall-back options. Most importantly, a well-reasoned "front-end" process with program initiation predicated on secretarial approval of the basic program need should give programs a sounder charter, more adequately programmed funding, and overall an improved opportunity to pursue an efficient development schedule.

The SIRCS Program, the Navy's experiment with the A-109 approach to systems acquisition, has progressed through an initial stage. Undoubtedly, with further experience in SIRCS and other programs following A-109, lessons will be learned for the best structuring of programs following this new acquisition policy. Such lessons learned are of crucial importance because in the implementation phase policy reform often falters. One can justifiably criticize certain aspects of A-109, but such criticism relates

to implementation provisions. Resolving these difficulties is the challenge facing the DOD. Failure to meet this challenge means impeding a policy reform that is long overdue and that offers great promise for a system in dire need of responses to its fundamental problems.

POSTSCRIPT

The Congressional Record of June 20, 1977, containing the Conference Report on H.R. 5970, Department of Defense Appropriation Authorization Act, 1978 revealed the following recommended restrictive language for the SIRCS Program.

> Of the funds authorized to be appropriated under section 201 for the Navy (including the Marine Corps) for research, development, test, and evaluation, an amount not to exceed $3,894,000 shall be available only for (1) defining a set of design specifications for the Shipboard Intermediate Range Combat System (SIRCS) program, and (2) conducting an open competition, to be conducted after such design specifications have been defined and to be based on such specifications, to select a contractor or contractors for the advanced development phase of such program. In developing such design specifications, the Secretary of the Navy shall include the best features of the designs developed by the three contractors which have been selected for the program before the date of enactment of this Act and such other features as the Secretary considers appropriate. A contract entered into under the competition required by this section may be for development of the entire system or for development of any independent subsection [sic] of the system.

The accompanying rationale for the Conferees' action, contained in the Conference Report, stated the following.

> The SIRCS program has followed the acquisition strategy of the Office of Management and Budget Circular A-109 and intends that two contractors be funded to build competitive prototypes of a new radar and new missile integrated with a fire-control computer system for shipboard use. The Navy presently is evaluating proposals submitted by three separate contractors for these components. Under the program as presently structured the Navy could not select the most desirable components from individual contractors but would have to fund continued development of the complete systems of two of the three contractors. This acquisition approach could cause continued development of less than optimum subsystems, a factor which exposes a potential shortcoming of the development procedures of

> OMB Circular A-109. Consequently, the House conferees emphasize that the language specified in Sec. 203 is a clear intent to exclude SIRCS from the A-109 process and made the funding authorized contingent upon this condition.
>
> The conferees agreed that the next step in the SIRCS program is for the Navy to define a "baseline" design containing the best features contained in, but not limited to, three funded contractors, and that this baseline SIRCS is to be submitted for open competition for the advanced development phase. Under this procedure the Navy has the flexibility to select or develop independent subsystems such as the radar or missile for independent contracts if such action is determined to be desirable and will provide the best possible weapons system.
>
> The conferees agreed to provide $3.9 million for the SIRCS program, with the understanding that the Navy uses the baseline approach to continue the program.

The above Congressional direction is interesting in that the criticism of the SIRCS Program relates only to the qualified charge that "This acquisition approach could cause continued development of less than optimal subsystems". Indeed, a fundamental objective of the SIRCS Program is to develop an optimized system not optimized subsystems.

The following statement in the Conference Report indicates that the Conferees have apparently misinterpreted the flexibility which the Navy has in managing the SIRCS Program.

> Under the program as presently structured the Navy could not select the most desirable components from individual contractors but would have to fund continued development of the complete systems of two of the three contractors.

This statement is literally true, but the constraint is only self-imposed and not binding in so far as management flexibility is concerned. The point is that based on Navy review of contractor concepts there is no current justification for exercising a perogative to modify the basic acquisition approach and to transfuse concept features. Should further development activities indicate that certain transfusion is in the best interest of the Navy, then one would expect that appropriate action would be taken to modify the acquisition strategy. In reality, there is a considerable amount of beneficial transfusion of best features as a consequence of the forces of competition. These competitive forces cause, for example, competitors to select features deriving from common government laboratory and corporate sources, and for winners and losers to gravitate to one another if there are residual best features in a loser's concept which would enhance that of a winner.

In response to the restrictive language of the FY 78 Defense Authorization Bill, the Secretary of the Navy has appealed to key Congressional leaders stating his objection to the action taken. It remains to be seen what the ultimate outcome will be for SIRCS and the current experiment with the A-109 approach as a consequence of final Congressional action on the FY 78 Budget.

THE PAYOFF OF PROCUREMENT PROFESSIONALISM

FEDERAL PROCUREMENT PERSONNEL: THEIR JOB-RELATED LEARNING

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This text is essentially the material found in Dr. Hood's award-winning article in the NCMA Journal. Dr. Hood's talk was extemporaneous but based on this text.

INTRODUCTION

Occupations differ from one another in the amount and kinds of further education they require of practitioners. (1) Moreover, the diversity of organizational situations in which practitioners of specific occupations find themselves differ from one another in amount and kinds of preparation required periodically for effective role performance.(2) One such field of practice with such dynamic diversity is that of federal procurement--the activities performed by many people in different organizations which acquire systems, supplies and services for the agencies of the federal government.(3)

The total annual federal procurement expenditure exceeds 60 billion dollars.(4) The size of this expenditure prompts people to be concerned about the integrity of the processes through which the expenditure is made.(5) The critical component in the process concerns the knowledge and skill possessed by personnel working in the procurement offices.(6)

The largest agency, in terms of both numbers of people working in procurement and dollars of expenditure, is the Department of Defense.(7) This agency established a career program for both military and civilian procurement personnel in specific terms of maintaining a conscious connection of these personnel with the institution of the Department of Defense.(8,9) The Defense Management Education and Training Board established a procurement training program specifically for civilian personnel.(10) Part of this program provided for specific job oriented courses to be taken during the procurement practitioners' progress from Grade GS-5 to Grade GS-13.(11) These courses are stipulated as "mandatory" because of the need within the DOD of a training program which sufficiently assures a minimum level of competence of its procurement practitioners.(12) Part of this need arises from the diversity of educational backgrounds and job experiences of these people.(13)

Reports are periodically made showing the number of personnel within the specific procurement occupations that have completed the mandatory courses required for their grade or rank. A recent report reveals that less than 50 percent of the civilian procurement personnel have taken the mandatory courses.(14)

This surfaces the question of how people within the respective ranks acquire the requisite knowledge and skills to perform their assigned duties and responsibilities in the procurement offices. Many other questions are subsequently raised. Did these people engage in some sort of individual or group learning effort independent of the established program? If they had, are they still doing so? How much effort do they spend in such learning? What is the content of their learning? What assistance did they have? What difficulties did they encounter? Can there be organizational changes which will foster this kind of learning effort? Can there be any changes in their preparation for learning about procurement work in either their education or experience?

Research Objective

The objective of the research reported here is to explore the self-learning projects of those persons working in the occupations of federal procurement. This exploration examines and analyzes (1) the extensiveness of the self-learning projects, (2) the content of the subject matter studied, (3) the strategy or method used, (4) assistance secured by the individual practitioner in deciding to begin a project, (5) the difficulties encountered during a project, (6) aids in accomplishing a project, (7) the role of learning for credit, (8) perceived changes in the employer organization to facilitate self-learning, and (9) perceived changes in the learner's preservice education and experience.

Significance of the Research

This research provides valuable information about the self-learning behavior of those persons working in the occupations of public procurement. It will present the extent of the learning projects attempted by the practitioners in public procurement and the amount of time they spend in job-related learning. Analysis of the data will indicate the types of help that those procurement practitioners seek in order to carry out their learning besides the obstacles they encounter. It will reveal the content of their learning projects and the methods they use to master that content. This research should provide a better understanding of the learning competence of procurement practitioners as well as the effect of their preservice education and experience as it affects their ability to learn.

Research Questions

As suggested by the preceding sections, nine research questions are explored:

RQ_1: How extensive are self-learning projects practice among procurement personnel?

RQ_2: What is the nature of the type of subject matter studied by procurement personnel in their job-related self-learning projects?

RQ_3: What is the nature of the learning strategy employed by procurement personnel in their job-related self-learning projects?

RQ_4: What is the nature of the assistance received by procurement personnel in deciding to begin job-related self-learning projects?

RQ_5: What is the nature of the source of difficulty encountered by procurement Personnel during their job-related self-learning projects?

RQ_6: What is the nature of the source of assistance received by procurement personnel during their job-related self-learning projects?

RQ_7: What is the nature of learning for credit in the job-related self-learning projects performed by procurement personnel?

RQ_8: What is the nature of the organization changes perceived by procurement personnel that facilitate job-related self-learning?

RQ_9: What is the nature of the changes in preservice education and experience perceived by procurement personnel that facilitates job-related self-learning.

Key Concepts and Terms

The key concepts and terms are briefly presented for the purpose of providing consistency as well as the criterion for usage.

Many different terms or expressions have been used for self-learning. These include self-education, self-motivation, self-teaching, independent study, individual learning, self-directed learning, and self-study. The term, "self-learner," is used to discuss this phenomenon of people who engage in learning activities without the use of a teacher.

This research is concerned with individuals working in the field of federal procurement at their job-related self-learning projects. These self-learning projects consist of a series of episodes totaling seven hours within a one-year period that have the purpose of not only gaining a definite knowledge and skill, but also retaining that knowledge and skill for at least two days.(15, 16)

RESEARCH DESIGN

This research is an exploration into the phenomena of the practice of job-related self-learning projects performed by civilian procurement personnel in the federal government. The goal of this type of research is the identification not only of variables but also of the relationships between and among variables.(17)

Sources of Research Data

Over 72,000 persons are employed in the procurement occupations by the federal government. These occupations comprise several occupational groups composed of both civilian and military personnel.(18) Of this latter number, slightly over 3,300 are employed by one federal agency.

Of this universe of 3,300 employees in the agency's procurement organization, 459 are assigned to one buying center. The GS grade levels for these 459 persons range from GS-5 through GS-16. At the center, GS grades 5 through 11 are, in the procurement occupation, considered to be training or entry grades. Persons within this grade are, for the most part, participating in a prescribed training program. The journeyman and senior levels are in grades GS-12 and higher. Of the 459 procurement personnel in the GS-1101 and GS-1102 series at the center, 340 are grade GS-12 and higher.(19)

From the population of 340 procurement practitioners, a sample size of at least 10 percent of the population, 34 persons, was selected. This sample size was dictated by the practical realities of the research situation. Selection of the sample was accomplished by a systematic random sample design. This selection procedure is considered the more rigorous. This sample design offers the advantages of providing for the stratification of the population by GS grade level and thereby avoids variability of the simple random design.(20)

Data Collection

The structured personal interview method is the principal means of collecting the data from the procurement personnel performing job-related self-learning projects. Additional data from the archives complements the interview data.

TABLE 1

LIST OF VARIABLES AND THEIR RESPECTIVE MEASUREMENT

Area	Variable	Type of Measurement
Adult Learner	Total Number of Projects	Interval/Ordinal*
	Total Number of Hours Spent	Interval/Ordinal*
	Job Role: Line/Staff	Nominal
	Management/Operative	Nominal
	Age	Interval/Ordinal*
	Civil Service Grade/Rank	Ordinal
	Formal Education Level	Ordinal
	Recency of Formal Education	Interval/Ordinal*
	Longevity of Current Grade/Rank	Interval/Ordinal*
	Longevity of Government Service	Interval/Ordinal*
	Suggested Organizational Changes	Nominal
	Suggested Preservice Education	Nominal
	Suggested Preservice Work Experience:	
	Varieites	Nominal
	Preferred	Nominal
Self-Learning Project	Subject Matter	Nominal
	Learning Strategy	Nominal
	Assistance in Deciding to Begin Project	Nominal
	Source of Difficulty During Project	Nominal
	Source of Assistance During Project	Nominal
	Learning for Credit	Nominal
	Time Spent on Each Project	Nominal
	Time Uility of New Knowledge	Nominal
	Status of Each Project	Nominal
	Job Role: Line/Staff	Nominal
	Management/Operative	Nominal

*Although interval measurement seems appropriate for these variables, the nature of the data is such that the assumptions for using interval data cannot be made, and ordinal measurement is therefore used.

Data Gathering Instrument

The data gathering instrument for this research, for the most part, replicates that used by Allen Though and two of his students, J. W. Fair and Cressy A. M. McCatty.(21)

Much of the content of the interview schedule, the probe sheets and project data sheet, is adopted from Fair. The probe sheet addressing the subject areas of the procurement occupations is taken from that developed and used by the staff of the Commission on Government Procurement.(23)

Data Analysis

The variables for which measurement is obtained are classified into two distinct groups: (1) the primary variables pertaining to the respective research questions, and (2) other relevant variables, including the demographic variables. These variables are listed in Table 1.

The descriptive function of the statistical analysis deals with the frequency of occurrences in each category of the primary variables. The inferential function presents statistical inferences about the distribution of the primary variables and the relationship of the primary variables with other variables and is accomplished by using nonparametric tests of significance. These tests are used because the parameters of the population from which the sample was drawn are unknown and no assumptions are being made about the population. These tests are applied to data of nominal and ordinal measurement.

For nominal measurement, the statistical tests used are the Chi Square test for goodness of fit, and the Chi Square test of independence and the Fisher Exact Probability test .95.

For ordinal measurement, the two statistical tests used are the Mann-Whitney U-test and the Spearman rank correlation. Although some of the variables listed in Table 1 are suitable for interval measurement, the assumptions for using the tests appropriate for interval data cannot be met in this research.(24)

To determine whether or not (1) a primary variable is a statistically significant variable in the population for the participation in self-learning projects and (2) a statistically significant association exists between the primary variables and the other variables, the analysis is accomplished by using as the independent observation the mode for each respondent.

RESEARCH FINDINGS

Sample

Application of the Chi Square test for goodness of fit to three demographic variables of both the sample and the population revealed that the sample drawn was representative of the population. Thus the ages, grade levels, and education levels of the sample are not unlike the population.

Research Question Number 1

RQ_1: How extensive are self-learning projects practiced among procurement personnel?

Number of Self-Learning Projects

Four-hundred-five job-related self-learning projects were performed by 32 learners of the 34 procurement personnel in the sample. The number ranged from as few as two projects to as many as 24 projects. The median number of projects equaled 11 for both the sample and the performers. The mean for the sample was 11.9 projects while the mean for the performers was 12.7 projects. Although the self-learners are not evenly distributed over the different levels of self-learning projects, the variation of the number of self-learners for the respective categories is such that it would suggest that self-learning activity tends toward a differential behavior in the population of procurement practitioners. (See Table 2.)

Since self-learning tends toward a differential behavior, the information presented in Table 3 reveals that job role (both line/staff and management/operative) provides a differential basis for such self-learning behavior.

Hours Spent on Self-Learning Projects

Thirty-two self-learners from the sample of 34 procurement personnel spent nearly 21,000 hours in self-learning activity. The number of hours ranged from as few as 132 hours to 1,840 hours. The median value was 578 hours for the 32 self-learners while the mean value was 655 hours. The variation of hours spent on self-learning projects by the self-learners is such that the time spent at self-learning is a significant differential behavior in the population of procurement practitioners. (See Table 2.)

Since spending time on self-learning projects is a differential behavior, the information in Table 3 reveals that job role provides a significant differential basis for the behavior.

Summary

Job-related self-learning activity for procurement practitioners is a significant differential behavior in that some engaged in self-learning activity more than others. Those that do perform more self-learning projects and spend more time in self-learning tend to be involved in management and staff work rather than operative and line work.

Research Question Number 2

RQ_2: What is the nature of the type of subject matter studied by procurement personnel in their job-related self-learning projects?

Distribution of Self-Learning Projects

Nearly three-fourths of the 405 self-learning projects performed are technical/business oriented. Over half are oriented exclusively to procurement office technical matters. The remainder are oriented toward human and conceptual skills.

Distribution of the Self-Learners

The distribution is concerned with a specific modal value reported for each self-learner. Nearly all of the self-learners confined their activity to the business/technical subjects with most of the latter being oriented to procurement/technical subjects. A differential preference exists for the procurement categories of subject matter for the job-related self-learning projects of procurement personnel. (See Table 2.)

TABLE 2

DIFFERENTIAL BEHAVIOR OF THE PRIMARY VARIABLES

Research Question	Primary Variable	Significant at .05
1	Number of Projects (Total)	No*
	Number of Hours (Total)	Yes
2	Types of Job Related Subject Matter	Yes
3	Learning Strategy	Yes
4	Assistance in Deciding to Begin Project	Yes
5	Difficulty Encountered During Project	Yes
6	Assistance Received During Project	Yes
7	Learning for Credit	No
8	Organization Changes to Aid Projects	No**
9	Preservice: (1) Education	No
	(2) Experience (Varities)	Yes
	(3) Experience (Specific)	Yes

*Significant at .1
**Significant at .2

TABLE 3

RELATIONSHIPS OF THE PRIMARY AND OTHER VARIABLES CONCERNING THE PROCUREMENT SELF-LEARNERS

Other Relevant Variables	Primary Variables: Number of Projects (Total)	Number of Hours (Total)	Suggested Organizational Changes	Suggested Preservice Education	Suggested Preservice Variety of Experience	Suggested Preservice Specific Experience
Number of Projects (Total)	NS	NS	NS	.16**	NS	.17**
Number of Hours (Total)	NS	NS	NS	NS	NS	NS
Job Role: Line/Staff	.07**	.05**	NS	NS	NS	NS
Management/Operative	.20**	.05**	NS	NS	NS	.20*
Age	NS	NS	NS	.12**	NS	.14**
Civil Service Grade	NS	NS	NS	.05**	NS	NS
Formal Education Level	NS	NS	NS	.17**	NS	.09**
Recency of Formal Education	NS	NS	NS	NS	NS	.12**
Longevity of Current Grade	NS	NS	NS	NS	NS	NS
Longevity of Government Service	NS	.10***	NS	NS	NS	NS

*Chi Square Test of Independence
**Mann-Whitney U Test
***Spearman Rank Correlation

Association with Other Variables

The information in Table 4 reveals that at the lower significance levels five variables tend to be associated with subject matter. Concerning job role, those self-learners performing staff duties confined their activities to only procurement subject matter while those performing procurement line duties included other subject categories. The time utility of the newly acquired knowledge is associated with subject matter studied in that subjects other than procurement have a much longer time utility. As to the time period for each self-learning project, projects concerned with procurement subject matter tend to last one week or less, while projects dealing with other subjects are evenly distributed over different time periods. Learning strategy (self-planned/other) is also associated in that procurement subjects were preponderantly self-planned, while other subjects were exclusively self-planned. Self-learners dealing with procurement subjects had more difficulty in their planning and evaluation of the projects.

Research Question Number 3

RQ_3: What is the nature of the learning strategy employed by procurement personnel in their job-related self-learning projects?

Distribution of Self-Learning Projects

Over half of the 405 self-learning projects were accomplished through a mixed strategy rather than one of several specific strategies. The strategies identified with self-learning (one-to-one and self-planned) were employed in nearly 18 percent of the projects.

Distribution of the Self-Learners

The distribution is concerned with a specific modal value reported for each self-learner. Although all categories of learning strategies are indicated by the sample of self-learners, the larger number of self-learners employ a mixed learning strategy while the next larger number seem to use the self-planned strategy. A statistically significant differential preference exists with respect to the learning strategy employed. (See Table 2.)

Association of Learning Strategy with Other Variables

The association of learning strategy with other variables is presented from the viewpoint of three different groupings of learning strategies: (1) mixed strategy or the others, (2) self-planned strategy or the others, and (3) combined one-to-one and self-planned learning strategy or the other strategies.

Mixed Learning Strategy/Other Strategy

From the information in Table 4, a significant association exists with time utility of newly acquired knowledge. When the utility is longer than one week, a mixed strategy as well as the other strategies is used. At lower significance levels, additional differential bases emerge. The type of assistance encountered during a project where the mixed strategy is used tends to occur in the planning and evaluation area, whereas the assistance occurs in organizing area when the other strategies are used. The mixed strategy tends not to be used in the projects having a completed status. Concerning job role, line procurement personnel tend to use other strategies.

TABLE 4

RELATIONSHIPS OF THE PRIMARY AND OTHER VARIABLES
CONCERNING THE PROCUREMENT SELF-LEARNING PROJECTS

	Primary Variables							
		Learning Strategy						
Other Relevant Variables	Subject Matter	(1) Mixed/ Specific	(2) Self-Plan/ Other	(3) Self 1-to-1/ Other	Assistance Deciding To Begin	Difficulty Encountered In Project	Assistance Received In Project	Learning for Credit
Time/Project	.2	NS	NS	NS	NS	.05	NS	NS
Job Role:								
Line/Staff	.1	.3	.1	.1	NS	.035	NS	NS
Management/Operative	NS	NS	NS	NS	NS	NS	.2	NS
Time Utility	.1	.035	.2	.3	NS	.2	NS	NS
Project Status	NS	.06	NS	NS	NS	NS	NS	NS
Subject Matter		NS	.15	NS	NS	.2	NS	NS
Learning Strategy:								
(1) Mixed/Specific			NS	NS	NS	NS	.1	NS
(2) Self-Planned/Other				NS	NS	NS	NS	NS
(3) Self 1-to-1/Other					NS	NS	NS	NS
Assistance in Deciding To Begin						NS	NS	NS
Difficulty Encountered During Project							.2	NS
Assistance Received During Project								NS

Self-Planned Learning Strategy/Other Strategies

The information in Table 4 shows that at lower significance levels, three associations appear--job role (line/staff), subject matter, and time utility of newly acquired knowledge. Line procurement personnel tend to use a strategy other than self-planned while staff procurement personnel tend to use the self-planned strategy. Self-planned learning strategy was used exclusively for subjects other than procurement while both self-planned and other learning strategies were used for procurement subjects. For new knowledge to be used for longer than one week, strategies other than self-planned tend to be employed.

Self-Planned and One-to-One Learning Strategies/Other Strategies

The information in Table 4 shows that at lower significance levels two associations appear.

The association with job role (line /staff) indicates that line procurement personnel tend to use strategies other than the self-planned and one-to-one strategies while staff personnel tend to use these strategies.

The association with the time utility of newly acquired knowledge reveals that when the new knowledge is used less than one week, the self-planned and one-to-one strategies tend to be used. For longer periods, other strategies are used.

Summary

The mixed strategy and the self-planned/one-to-one strategies were not only the most frequently employed, but also tended to associate with other variables in the lower levels of significance. The job role (line/staff) of the self-learners provides the differential basis for the use of the type of learning strategy in that line procurement personnel tended to employ other strategies in addition to self-planned/one-to-one. Also, the time utility of the newly acquired knowledge provided another differential basis for the type of learning strategy used in that self-planned strategy is used for the shorter periods of utility.

Research Question Number 4

RQ_4: What is the nature of assistance received by procurement personnel in deciding to begin job-related self-learning projects?

Distribution of Self-Learning Projects

Assistance in deciding to begin a project was received in slightly over 10 percent of the projects. The procurement practitioners in the sample did not receive this kind of assistance in 90 percent of the projects.

Distribution of the Self-Learner

The modal value reported for the 32 self-learners reveals a distribution where all but one of the self-learners did not receive assistance in deciding to begin their self-learning projects.

This shows that a statistically significant differential behavior exists in the population for not receiving assistance in deciding to begin a project. (See Table 2.)

Association of Assistance Received in Deciding to Begin a Self-Learning Project

From the information presented in Table 4, this variable is independent of the other variables.

Summary

The procurement practitioners do not receive assistance in deciding to begin their self-learning projects. There is no differential basis for the prevalence of this behavior.

Research Question Number 5

RQ_5: What is the nature of the source of difficulty encountered by procurement personnel during their job-related self-learning projects?

Distribution of Self-Learning Projects

Organizing the materials for the procurement job-related self-learning projects accounted for 40 percent of the projects' sources of difficulty; organizing both materials and people accounted for nearly 56 percent of the sources of difficulty. Planning the job-related self-learning project accounted for over 26 percent of the sources of difficulty. Slightly less than one-fifth of the projects revealed that evaluation of the project was the principal source of difficulty.

Distribution of Self-Learners

The distribution concerned with a specific modal value reported for each self-learner reveals the organizing of materials for the self-learning projects having the highest frequency.

A statistically significant differential occurrence exists in the distribution with respect to the sources of difficulty encountered on job-related self-learning projects.

Association of Sources of Difficulty Encountered During Self-Learning Project

From the information presented in Table 4, five other variables are associated with difficulty encountered, thus revealing a differential basis. The source of difficulty in projects lasting less than one week occurs in the organizing of the materials and people. In projects lasting longer than one week, it occurs in the planning and evaluation of the project. While line procurement personnel report the sources of difficulty in both the organizing and planning/evaluation categories, staff procurement personnel report the source of difficulty only in the organizing area.

Assistance in planning/evaluation and organizing occurred directly with the reported sources of difficulty. Difficulty in planning/evaluation tends to occur when the newly acquired knowledge is required to be retained longer than one week. The source of difficulty tended to occur in the organizing of materials and people when procurement subjects were studied while difficulties in planning/evaluating tended to occur when subjects other than procurement were studied.

Summary

For the self-learning projects, much of the difficulty had as its source the organizing of materials. This differential occurrence was also prevalent among the self-learners. The differential bases for these occurrences seem primarily to be: (1) the job role of the self-learner, and (2) the time spent on a job-related self-learning project; and secondly: (1) the time utility of new knowledge, (2) the subject matter studied, and (3) the assistance encountered during a project.

Research Question Number 6

RQ_6: What is the nature of the source of assistance received by procurement personnel during their job-related self-learning projects?

Distribution of Self-Learning Projects

The organizing of materials and people is a substantial source of assistance to the procurement people during the self-learning projects. With these two categories comprising over 81 percent of the projects, planning as a source of assistance is a distant third place, being cited in less than 16 percent of the projects.

Distribution of the Self-Learners

The distribution concerned with a specific modal value reported for each self-learner reveals that, as with the self-learning projects, organizing people and materials show the highest frequency. A statistically significant differential occurrence exists with respect to the sources of assistance encountered in job-related self-learning projects.

Association of Source of Assistance Encountered During Self-Learning Project

For the information presented in Table 4 a differential basis emerges with three other variables (job role--management/operative; learning strategy used--mixed/specific; and difficulty encountered). Assistance in terms of organizing people and materials occurs when a specific learning strategy is used as opposed to a mixed strategy. Assistance in the form of organizing people and materials tends to occur with the same forms of source difficulty. Assistance in the form of organizing people and materials occurs almost exclusively for operative level procurement personnel in their self-learning project, whereas assistance for management level procurement personnel occurs in both organizing and planning/evaluating. This is the case in the first two modal groupings.

Summary

For both self-learning projects and the self-learners, the primary source of assistance encountered during a job-related self-learning project is the organizing of resources--people and materials. A differential basis tends to emerge with variables for (1) job role (management level/operative level), (2) learning strategy (mixed/specific), and (3) source of difficulty encountered.

Research Question Number 7

RQ_7: What is the nature of learning for credit in job-related self-learning projects performed by procurement personnel?

Distribution of Self-Learning Projects

Less than 5 percent of the self-learning projects were taken for credit.

Distribution of Self-Learners

The distribution concerned with a specific modal value recorded for each of the self-learners reveals that none of the self-learners had a mode (the most frequencies) of learning for credit.

Association of Learning for Credit with Other Variables

Since none of the self-learners had a modal value indicating learning for credit, this means that none of the other variables employed in this research are associated with learning for credit.

Summary

Learning for credit is not an important consideration in the undertaking of a job-related self-learning project by procurement personnel.

Research Question Number 8

RQ_8: What is the nature of the organization changes perceived by procurement personnel that facilitate job-related self-learning?

Distribution of Self-Learners

The distribution of 34 self-learners among the five categories of perceived organization changes to facilitate their job-related self-learning activity reveals a differential in the categories at the lower significance levels. (See Table 2.)

Association of Organization Changes to Facilitate Learning with Other Variables

Table 4 reveals that no association exists between organization changes and other variables.

Summary

Although the distribution of self-learners is somewhat significant statistically, two categories oriented toward resource commitment account for over 50 percent of the self-learners. Organization changes to facilitate self-learning are not differentiated with self-learning activity.

Research Question Number 9

RQ_9: What is the nature of the changes in preservice education and experience perceived by procurement personnel that facilitates job-related self-learning?

Preservice Education (Fields of Study)

The distribution of the 34 self-learners among the six categories of fields of study does not reveal a differential preference. (See Table 2.)

Differentiation between fields of study basis emerges with total number of projects. Those with a business field of study orientation tended to have more job-related self-learning projects. Most of those in GS grade levels higher than GS-12 tended to prefer a business field of study. The business field of study tended to be preferred by the older procurement practitioners.

Preservice Experience (Variety)

The distribution of the 34 self-learners among the categories of variety of experience reveals a differential preference. (See Table 2.)

The information in Table 3 indicates no differentation of preservice experience variety with the other variables.

Preservice Experience (Specific)

The distribution of the 34 self-learners among the categories of specific preservice experience reveals differential preferences. (See Table 2.)

The information in Table 3 indicates a differentiation of specific preservice experience with five variables. Those who preferred a specific preservice experience tend to have more recently completed their formal education. A specific type of preservice experience to facilitate their self-learning activity is preferred by both those with and without college degrees. Those in management roles also prefer a specific type of preservice experience.

Summary

The type of preservice education in terms of fields of study is not significant. To facilitate self-learning activity, however, the number of self-learning projects is significantly different between preservice education categories at a level less than the stated level. Age and formal education are similarly differentiated.

Although the variety of preservice experience is a significant behavior among self-learners, it is not significantly differentiated with other variables.

The specific type of preservice experience is a significant behavior among the self-learners. At lower levels of significance, it is differentiated with self-learning activity, level of formal education, the job role of self-learners, their age and recency of their formal education.

Incidental Findings

There are findings which are incidental to the research. First, the differences between high learners and low learners in terms of self-learning activity are discussed.

Finally, an example is one such project that was performed by one of the respondents.

Extensiveness of Self-Learning Activity

Some of the procurement personnel interviewed engaged in more or greater amounts of self-learning activity than others. Those self-learners who engaged in substantial self-learning activity are referred to as high learners. Conversely, those that engaged in minimal self-learning are referred to as low learners. During the course of the interviews, some individuals would apologize for not having done any or as much self-learning activity as they think others have. On the other hand, others would brag about their doing more self-learning than others. Regardless of which, each would offer unsolicited reasons why they do engage in a lot or very little self-learning. These reasons seem to fall into three groups--attitude, interpersonal relations and organizational identity--and differentiate the high learners from the low learners.

The attitude of the high learners is revealed by their enthusiasm for their job and career field. They seem to thoroughly enjoy their work and its many challenges. The attitude of the low learner was reflected by somewhat lower levels of enthusiasm. Although some low learners seem to enjoy their work, others simply tolerate it. Some had less than five years of service remaining until they were eligible for retirement. A few felt that they knew all that was necessary to know.

High learners seem to possess better interpersonal skills than the low learners. Many of the low learners seem to have difficulty in the interpersonal relations with their peers, superiors and subordinates. Moreover, their level of aspiration seemed much lower than that of the high learners. Low learners felt they would not be promoted whereas high learners aspired to higher level jobs. Two of the high learners have recently been promoted.

Finally, the high learners seem to be identified with the more prestigious and publicized organizations. They seem to work in jobs where they are highly visible to the top executives. Low learners seem to be located in the less prestigious and less visible organizations. Several respondents apologized for having so few projects. They further indicated that in past periods when their organization was the more prestigious and publicized, they had many more job demands and engaged in many more self-learning projects.

Example of a Self-Learning Project

One respondent had worked for several years in an office where the pricing of proposals was performed by the pricing staff. This individual was recently assigned to an office where the pricing of proposals was performed by the incumbents rater than the pricing staff. Although this individual had had experience in pricing proposals, he felt that he needed to know how to use other techniques. One such technique he wanted to learn to use was the improvement or learning curve, since this technique had immediate application. That is, the pricing task confronting him required the use of this technique. Having identified what he wanted to learn, he consulted one of the supervisors in the pricing office as to how he might learn to use the technique. The pricing supervisor first loaned this respondent a couple of books, citing the passages to study and set up a series of several meetings where this individual as a learner would have to accomplish several tasks prior to the meeting. In this case, it involved using the technique on his work assignments. After several meetings, which took place over a four month period, the individual and his tutor, the pricing supervisor, were satisfied that he possessed sufficient skill to use the technique in his current assignment.

This example illustrates how an individual could conduct a self-learning project. He was ready to learn a specific knowledge and skill. He employed a tutorial or one-to-one learning strategy using an expert. The job demands decided that he should begin such a learning project. His main difficulty was deciding how much to learn. His major source of assistance was his tutor, an expert. He received no documentary credit for this learning endeavor. He spent over forty hours of his own time both on and off the job and with about ten hous being spent with the expert. The utility of the newly acquired skill was immediate and will continue throughout this new duty assignment and, perhaps, future assignments. For all practical purposes, the self-learning project is completed.

Conclusions

1. Job-related self-learning is extensive in the federal procurement occupations and the extensiveness is differentiated by the individual job roles.
2. Subject matter studied is not only preponderantly procurement office oriented, but also is oriented toward applications of new as well as existing knowledge.
3. The self-planned and one-to-one learning strategies are the dominant ones for job-related self-learning activity.
4. Receiving assistance in deciding to begin a project is not an inherent part of job-related self-learning activity of procurement personnel.
5. Finding the knowledge resources--materials and people--tends to be the major source of difficulty in job-related self-learning projects.
6. Finding knowledge resources--materials and especially people--tends to be the major source of assistance encountered during a job-related self-learning project.
7. Learning for credit is not inherent to the self-learning activity.
8. Changes in organization are not too important in job-related self-learning activity.
9. Both preservice education and work experience preferences are important in job-related self-learning activity.

Implications for Management

From a practical viewpoint, management includes those who are concerned with in-service professional development of procurement practitioners. This includes not only members of the procurement career boards, but also (1) those executives, managers, supervisors involved in procurement operations within government agencies, and (2) the administrators, department heads, teachers, writers and librarians of the various schools and training organizations, both government and proprietary.

Because of budgetary constraints, education and training faces a financial crisis and one alternative is the use of independent study. The Civil Service Commission is encouraging more active programs of occupation-oriented self-education and training throughout the government. The Federal Personnel Manual stipulates that the head of each agency is responsible for encouraging the self-education, self-improvement, and self-training of the employees of the agency. President Lyndon B. Johnson directed the heads of the agencies to monitor the effectiveness with which self-development is encouraged at all levels. The Government Employees Training Act, P.L. 85-507, as codified

in Title 5 of the United States Code, Chapter 41, recognizes that it is necessary and desirable that employees' self-education, self-improvement, and self-training be supplemented by government-sponsored programs.

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THE DARCOM PROCUREMENT INTERN PROGRAM - A MAJOR INITIATIVE IN MEETING THE NEED FOR TOMORROW'S PROCUREMENT PROFESSIONALS

by

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INTRODUCTION

Each year the DARCOM procurement community awards billions of dollars for everything from housekeeping services to the research/development and production of major weapons systems. There is an obvious need for well trained, competent procurement professionals if these funds are to be properly and prudently awarded and managed. The research effort showed that the DARCOM Procurement Intern Program is meeting this need.

RESEARCH APPROACH

The objectives of the research effort were:

1. Evaluate the current DARCOM procurement intern program to determine how well the program is providing graduate interns to function as procurement professionals for estimated vacancies.

2. Develop recommendations for improvement of estimating DARCOM needs, recruitment, preparation and retention of personnel for a career in procurement.

Some of the specific questions to be explored in the project were:

1. Is the training given to interns effective? That is, is the graduate intern capable of functioning as a procurement professional?

2. Is the program long enough?

3. Is classroom training being coordinated with intern's on-the-job training assignments?

4. Is there a need for sequencing of training?

5. What career management actions are necessary or desirable to enhance the procurement intern program?

In addition to the traditional literature search, a questionnaire was distributed to 244 DARCOM procurement interns and graduate DARCOM procurement interns at the major subordinate commands (MSC's). There were 28 specific questions and two questions which allowed for general comments. The questionnaires were distributed with self-addressed envelopes to insure anonymity of replies. The responses to the questionnaires were subjected to both computer analysis and manual analysis.

Approximately 100 structured interviews were conducted. The majority of interviews were with procurement managers and PCO's at the major subordinate commands. Individuals in Civilian Personnel Offices and in Recruitment activities were also interviewed. Regression analysis and personnel flow modeling were explored as possible methods of estimating intern intake requirements.

WHY A PROCUREMENT INTERN PROGRAM?

The Army Procurement workforce is composed of roughly 3,500 individuals, the majority of whom (90.1 percent) are in the following job series:

1101 General Business and Industry

1102 Contracting and Procurement

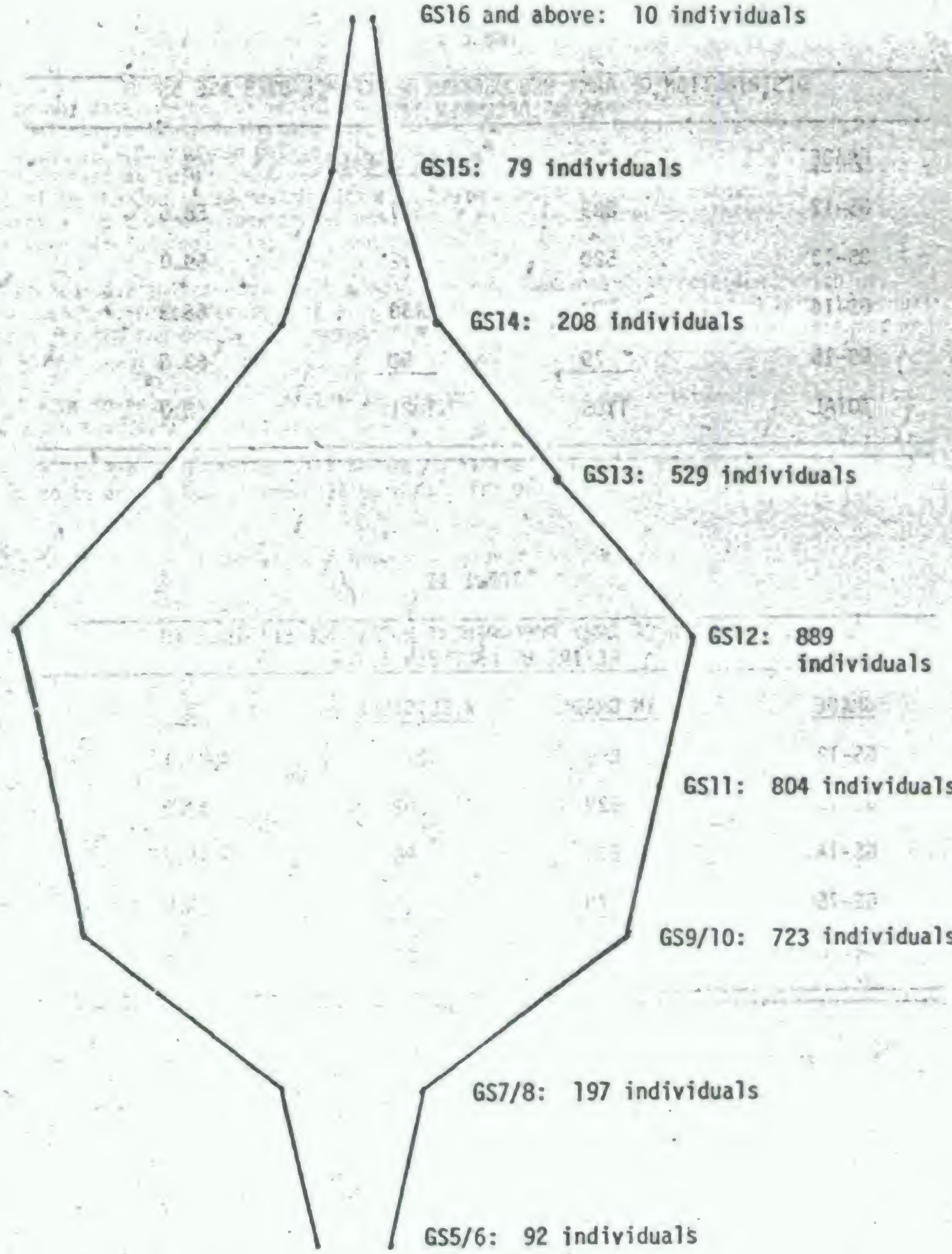
1103 Industrial Property Administration

1150 Industrial Specialist

The bulk of the workforce, 73.4 percent are in the 1102 Contracting and Procurement series. The distribution of the workforce by grade is depicted in Figure 1. For each grade level the number of individuals is graphically portrayed by the width of the diagram. Forty three point three (43.3) percent of the workforce is concentrated in grades 9 through 11. Forty six point eight (46.8) percent are in grades 12 through 15.

In December of 1975, 60 percent of the individuals in grades GS12-15 were over age 50. Table I presents a distribution of these individuals. Thirty five point four (35.4) percent of the individuals in grades GS12-15 will be eligible for retirement by December of 1978. Table II portrays the distribution by grade.

While one must be concerned with eventually replacing these individuals, it is of equal concern that their skills and expertise be utilized to train a replacement workforce to the same degree of professionalism. Since the preponderance of the Army's procurement workforce resides in the DARCOM community, it is critical that DARCOM maintain a viable means of developing procurement professionals with the requisite talent to accomplish its mission.



DISTRIBUTION OF ARMY PROCUREMENT WORKFORCE BY GRADE

FIGURE 1

TABLE I

DISTRIBUTION OF ARMY PROCUREMENT WORKFORCE OVER AGE 50
AS OF DECEMBER 1975

GRADE	# IN GRADE	# OVER AGE 50	%
GS-12	889	521	58.6
GS-13	529	312	59.0
GS-14	208	138	66.3
GS-15	79	50	63.3
TOTAL	1705	1021	60.0

TABLE II

DISTRIBUTION OF ARMY PROCUREMENT WORKFORCE ELIGIBLE TO
RETIRE BY DECEMBER 1978

GRADE	# IN GRADE	# ELIGIBLE	%
GS-12	889	276	31.1
GS-13	529	202	38.2
GS-14	208	96	46.2
GS-15	79	30	38.0
TOTAL	1705	604	35.4

WHAT IS THE DARCOM PROCUREMENT INTERN PROGRAM?

INTRODUCTION

The DARCOM Procurement Career Intern Program is a comprehensive training program which prepares selected individuals for journeyman level performance in the 1101, 1102, 1103, or 1150 job series. It provides the background for subsequent progression into middle and upper level positions in the procurement career field.

Interns are, for the most part, recruited through the Professional and Administrative Career Examination (PACE). They are started at the GS-5 level and after a year are promoted to GS-7. For their third year of training they are transferred to a permanent duty location (PDL) where they receive a GS-9. This structured 3-year development program consists of:

1. Formal school training which is accomplished at designated DOD schools. Normally, the training consists of formal classroom instruction. These formal training courses are distributed throughout all three years of the intern program.

2. First and second year on-the-job training (OJT) consists of in-depth rotational training and is accomplished at the career intern's designated training site - one of DARCOM's major subordinate commands.

3. Third year specialized OJT consists of intensive training accomplished at the DARCOM career intern's PDL and may include rotational assignments.

4. Successful completion of each phase is a prerequisite to commencement of the next phase and to advancement to higher grade levels.

During the first and second years, over 3,000 hours are devoted to structured rotational assignments and 440 hours are devoted to formal schools training. In the third year specialized technical training assignments account for some 1,500 hours, and formal schools training account for a minimum of 192.

RECRUITMENT

The DARCOM Procurement Intern Program is centrally managed and funded. HQ DARCOM maintains a pool of spaces against which interns are slotted regardless of their physical location. HQ DARCOM provides funds for the pay of the intern, his benefits, TDY travel and per diem, and authorized permanent change of station allowances. The centralized concept eliminates the responsibility of local agencies having to provide manpower spaces and funds for the career intern. It also eliminates the possibility of interns being subjected to local reductions-in-force.

DARCOM has three Field Place Offices (FPO) that accomplish recruitment of procurement interns. They are located in Philadelphia, Pa.; Atlanta, Ga.: and Davenport, Iowa. The FPO representatives have the authority to make firm offers of employment to interested and qualified personnel.

There are currently two methods of entering the procurement intern program - internal placement or the Civil Service Commission Register. Internal placement is accomplished by use of PSA Announcement 1-74, an open, continuous announcement. Test 500 is the primary measuring instrument used to compare applicants.

Prior to October 1974, the Federal Service Entrance Examination (FSEE) was used to establish eligibility on the Civil Service Commission Register. That test has been replaced by the Professional and Administrative Career Examination (PACE). The PACE is designed to measure abilities in five areas:

I. Ability to understand and interpret complex reading material, and to use language where precise correspondence of words and concepts makes effective oral and written communication possible.

II. Ability to make decisions or take action in the absence of complete information, and to solve problems by inferring missing facts or events to arrive at the most logical conclusion.

III. Ability to discover underlying relations or analogies among specific data where solving problems involves information and testing of hypotheses.

IV. Ability to discover implications of facts; to reason from general principles to specific situations as in developing plans and procedures.

V. Ability to perform arithmetic operations and solve quantitative problems where the proper approach is not specified.

These five areas are scored independently with various weightings and combinations of area scores used in determining ratings for six different occupational categories. An individual is considered for employment only if he earns ratings of 70 or higher for the specific occupational category being used. The career fields typically included in each of the occupational categories are as follows:

Category A: Personnel Administration, Management Analysis, Social Insurance Administration, General and Criminal Investigation, Customs Inspection, Public Health Program Management, Veteran's Administration (VA) and Social Security Administration (SSA) Claims Examining and Public Information.

Category B: Economics, Psychology, Taxation, Budget Administration, CONTRACTING AND PURCHASING, and Financial Institution Examining.

Category C: Automated Data Processing.

Category D: Contact Representative Positions (mainly with the VA and SSA).

Category E: Writing and Editing.

Category F: Alcohol, Tobacco, and Firearms Inspection.

The FPO's contact an average of 11 individuals for each intern accepted into the program. About 1/4 of these individuals are interviewed and only about 1/3 of those interviewed are hired. The PACE scores of accepted interns generally range from 95 to 110 and average approximately 98 to 99.

LEARNING BY DOING = OJT

The DARCOM Procurement Intern Program stresses "hands-on learning." During the first two years, interns are given specific amounts of on-job rotational assignments in eight different areas (see Table III). These learning by doing assignments ensure that the interns have actual work experience in all the important aspects of procurement.

During the Small Purchases rotational assignment, the intern learns when to use oral or written solicitation. He determines and recommends appropriate award of solicitations and he gets experience in the administration of those awards.

The Formal Advertising OJT consists of 480 hours. In this segment the intern is involved with all facets of formal advertising from determining the adequacy and completeness of a procurement package through award of the Invitation for Bid (IFB). He learns how to establish, review, and maintain a list of sources of supply; how to prepare the IFB; and how to conduct a bid opening. He gains experience in the evaluation of bids, the handling of late bids and mistakes in bids, and the difference between responsiveness and responsibility. He is also exposed to the procedures involved in protests of awards and the techniques of Two-Step Formal Advertising.

The intern completes a total of 320 hours of OJT in the Contract Pricing area. In this phase of his OJT, the intern learns the difference between, and how to perform, price analysis and cost analysis. He becomes proficient in the use of the Weighted Guidelines technique to develop a profit objective and, where possible, participates as a member of a Should Cost Team. The intern learns the importance and interfaces of the technical evaluation, the audit report, the Independent Government Cost Estimate, and contract pricing.

TABLE III

ROTATIONAL TRAINING ASSIGNMENTS FIRST & SECOND YEAR

TOPIC	TRAINING HOURS
Small Purchases	320
Formal Advertising	480
Contract Pricing	320
Negotiation	640
Contract Management	480
Procurement Policy	320
Production Management	240
Related Procurement Subjects	240

In the Negotiation block of his OJT the intern spends a total of 640 hours developing mastery over all phases of contract negotiation procedures from receipt of the Procurement Work Directive through contract close out. He becomes familiar with the various types of negotiation authority and the preparation of determinations and findings. He prepares and issues Requests for Quotations and Requests for Proposals and negotiates the various elements of a proposal up to the point of contract execution. He participates in both competitive and noncompetitive negotiations and prepares the additional justification for noncompetitive negotiations.

During his 480 hours in the Contract Management area, the intern is exposed to all aspects of contract administration from the time of award of the contract through final disposition of the completed contract file. He learns the comparative responsibilities of the Government and contractor in obtaining performance, and the contract management functions and responsibilities of the PCO, ACO, and TCO. He prepares and learns the differences between change orders and supplemental agreements, and processes requests for priorities assistance. He becomes involved with property administration, labor relations, disputes/appeals, and terminations for convenience as well as default.

In the Procurement Policy area, the intern participates in the development and implementation of policy and participates in the procurement reporting process.

A total of 240 hours are devoted to the Production Management area. Here the intern learns the purpose and objectives of mobilization planning and how production lead time impacts on cost, delivery, and procurement method. He becomes familiar with Material Allocation, Bills of Material, the Master Urgency List, and the Army Materiel Plan. He performs the various methods of expediting delivery and learns the role of the production member on a Pre-Award Survey Team.

Two hundred forty hours are devoted to Related Procurement Subjects. This block of OJT focuses on the interrelationship of Materile Management, Quality Assurance, Maintenance, Comptroller, Automatic Data Processing, Engineering, Commodity Management, Data Management, and Project Management with the Procurement function.

In the third year of the intern program, effort is concentrated on in-depth technical on-the-job training in one of the four following job seriees:

General Business and Industry (GS-1101)

Contract and Procurement (GS-1102)

Industrial Property (GS-1103)

Industrial Specialist (GS-1150)

Depending upon the target journeyman assignment, 1,528 hours are devoted to specialized training and 192 hours are devoted to formal classroom training. This specialized technical training is designed so that the intern will be capable of performing as a professional at its conclusion.

FORMAL SCHOOLS TRAINING

While the DARCOM intern program concentrates on OJT, it does not ignore formal schools training. Between 888 hours and 632 hours are devoted to classroom training depending on the target journeyman assignement. A minimum of eight courses are completed during the three years of the program. Upon completion of the program, the intern has attended all mandatory courses for the entry level (GS-5 through 8) and the majority of mandatory courses for the intermediate level (GS-9 through 12) in the procurement career program. The courses are time phased throughout the program so that the intern receives maximum benefit from the courses. In addition to the core courses which all interns take, there are specialized courses for those going into certain journeyman assignments. Those entering the GS-1150 series attend the Production Management course; those entering the GS-1103 series attend the Industrial Property Administration course; and those who are scheduled to become GS-1102 Price Analysts attend the Introductory Quantitiative Analysis course. Table IV depicts the formal schools training.

TABLE IV

FORMAL SCHOOLS TRAINING

COURSE	TRAINING HOURS
DARCOM Orientation Course for Career Interns. (First 120 days)	80
Defense Small Purchases. (Prior to the Defense Procurement Management Course, but not later than 120 days.)	40
Defense Procurement Management Course. (First 6 months)	160
Principles of Contract Pricing. (Second year)	80
Defense Contract Negotiation Workshop. (Second year)	40
Automatic Data Processing Orientation Seminar. (Second year)	40
Contract Administration Course. (All third year)	120
Government Contract Law. (All third year)	72
Production Management Course. (GS-1150 only)	256
Introductory Quantitative Analysis. (GS-1102 Pricing only)	160
Industrial Property Administration. (GS-1103 only)	112

HOW MANY INTERNS ARE NEEDED?

Procurement interns are one source of the manpower required to meet expanding workload requirements or to replace those procurement personnel who leave DARCOM because of retirement, resignation, death, or transfer to another organization. In an attempt to forecast their procurement intern

requirements, DARCOM conducts an annual survey throughout the field commands and organizations. The survey information is summarized and sent to HQ DARCOM where it is reviewed and tabulated to arrive at the total number of interns needed. Forecasts of intern requirements based on this field survey have been inaccurate in the past, usually in excess of the actual number needed. Therefore, a different approach to intern requirements forecasting is needed which will provide more accurate projections.

Two approaches that appear to have good potential are being investigated: a personnel flow model, and regression. Regression equations will be developed if an adequate historical data base can be located. The immediate effort involves designing and programming a personnel flow model.

Using actual personnel data currently available from the Civilian Personnel Information System (CIVPERSINS) as input, this personnel flow model will forecast annual procurement personnel requirements, of which interns are a part, for up to six years in the future. Figure 2 describes the model graphically.

As currently designed, gains to a procurement personnel pool will be in one of two groups, intern or all others. Losses from the pool will also be in one of two groups, retirements or all others. The model detail can be expanded later if desired.

Briefly, the model logic is as follows. Beginning with the actual inventory of procurement personnel in DARCOM, probable losses during the next year due to retirement are generated based upon Civil Service Commission retirement rates. Then, losses due to other reasons are generated using loss rates based upon 2.5 years of history in CIVPERSINS. Some members of the remaining workforce are promoted using CIVPERSINS promotion rates. Vacancies thus created are then filled by some combination of intern gains and other gains, depending upon hiring policy, to arrive at the desired manpower level. Summary reports are printed and the cycle is repeated for each forecast year desired.

IS THE PROCUREMENT INTERN PROGRAM DOING ITS JOB?

DATA BASE

A total of 244 questionnaires were distributed. Two hundred two responses were received, out of which 12 questionnaires were rejected for various reasons. The questionnaire data base, thus, consists of 190 respondents. The majority (40 percent) of those responding to the questionnaire were second year interns; however, there was a good sampling of all stages of training. First and third year interns each accounted for approximately 22 percent of the respondents and graduate interns accounted for some 16 percent. The grades of the respondents ranged from GS-5 to GS-13. Information garnered from approximately 100 structured interview was also utilized.

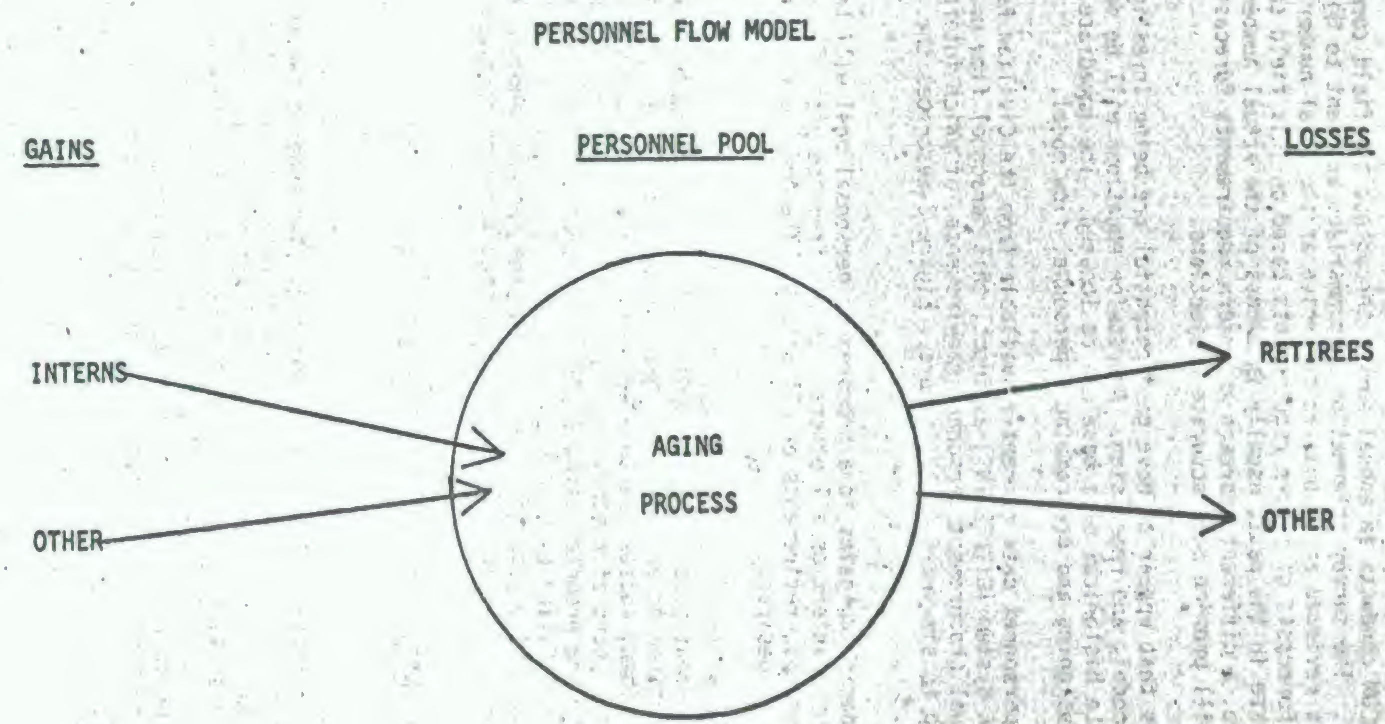


FIGURE 2. GRAPHIC OF PERSONNEL FLOW MODEL

INTERN PROFILE

The majority of DARCOM Procurement interns entered the program through the FSEE or PACE examination. Only 3.16 percent entered the program through internal placement techniques. Approximately 70 percent of the interns are nonveterans who have generally entered the program soon after completing college. Some 57 percent entered the program between the age of 20 and 25. Few, only 2.11 percent, were over 35 years of age when they entered the program.

The educational level of the respondents is very high when contrasted with the educational level of the Army's civilian procurement workforce. Ninety two point eleven (92.11) percent of the interns have at least a Bachelor's degree compared with 44.48 percent of the GS12-GS15 procurement careerists. Table V presents the various educational levels of procurement interns and the educational levels of the GS12-GS15 procurement professionals. Few interns have advanced their educational level since entering the program. Only 15 individuals have moved to a higher level. Ten of these individuals have completed a Master's degree since entering the program. The educational background of the interns is quite varied. The majority majored in one of the Social Sciences, few have had any appreciable education in Engineering or Law. Surprisingly, 52.63 percent have had less than nine semester/quarter hours of college credit in Business and Commerce subject areas.

VARIETY OF OJT

Three questions were designed to ascertain the amount and variety of procurement experience an intern receives.

The first question measured the various types and dollar values of contracts the interns had written. As Table VI shows, there was a wide variety of contract types and dollar values. The experience the interns are receiving is excellent compared with the mix of contracts in the Department of the Army. In fact, Table VII clearly shows that they are exposed to more types of contracts than one would normally expect given the available mix of contracts. The average number of different types of contracts and dollar values was 3.25. This average was distributed by stage of training as follows:

First year	1.90	Third year	3.88
Second year	2.63	Graduate	5.10

The second question measured the different types of procurement actions the interns had accomplished. It was concerned with determining the intern's exposure to various procurement methods such as: Small Purchases, Formal Advertising, Two-Step Formal Advertising, Competitive Negotiation and Sole Source Negotiation. In all but three areas - Two-Step Formal Advertising, Off-Shore Procurements, and 8(a) contracts - more than 35 percent of the

EDUCATIONAL LEVEL: ARMY PROCUREMENT CAREERISTS GS12 - GS15
COMPARED TO DARCOM PROCUREMENT INTERNS

GRADE	LESS THAN HIGH SCHOOL	HIGH SCHOOL	1 TO 3 YEARS COLLEGE	4 YEARS NO DEGREE	BA/S	MA/S	PhD
GS12	12	358	171	15	285	47	1
GS13	4	162	118	4	177	63	1
GS14	-	39	35	5	77	52	-
GS15	-	13	11	-	30	24	1
TOTAL	16	572	335	24	569	186	3
%	0.94	33.5	19.6	1.4	33.4	10.9	0.18
INTERNS	1	2	10	2	157	17	1
%	0.53	1.05	5.26	1.05	82.63	8.95	0.53

TABLE V

TABLE VI

TYPES AND DOLLAR VALUES OF CONTRACTS

Question #1

TYPE/$	NO. OF INTERNS	% OF THOSE ANSWERING
FP w/EPA	43	24.71
FFP $10,000 to 99,999	168	96.55
FFP #100,000 to 999,999	116	66.67
FFP over $1,000,000	44	25.29
FPI $10,000 to 99,999	11	6.32
FPI $100,000 to 999,999	9	5.17
FPI over $1,000,000	10	5.75
CPFF $10,000 to 99,999	48	27.59
CPFF $100,000 to 999,999	37	21.26
CPFF over $1,000,000	11	6.32
CPIF $10,000 to 99,999	12	6.90
CPIF $100,000 to 999,999	10	5.75
CPIF over $1,000,000	6	3.45
CPAF	4	2.30
T&M	24	13.79
LH	12	6.90

interns have had some experience. Again, the wide breadth of experience is evident (see Table VIII). The overall average number of different types of actions was 4.89. This average was distributed by stage of training as follows:

First year	2.52	Third year	6.45
Second year	4.50	Graduate	6.81

The third question assessed the intern's involvement with actions such as Terminations, Protests, Claims, and Mistakes in Bids. Again, the breadth of experience is extensive (see Table IX). The average number of different types of actions is 4.85 which was distributed as follows:

First year	2.42	Third year	5.90
Second year	4.24	Graduate	6.81

The responses to these three questions clearly show that, on the whole, the interns are being given broad OJT in all important aspects of contracting.

Further analysis of this data revealed a distinct relationship between the variety of experience and how well the intern rated the program in preparing one for journeyman level performance. Those who had rated the program excellent had a significantly greater variety of experience than those who rated the program poor (see Figure 3).

THE CLASSROOM

Interns are receiving the required formal training. A total of 98.95 percent have either completed the Defense Procurement Management Course or are scheduled to attend the course within six months. With the exception of Government Contract Law (49.47 percent), at least 70 percent of the interns have either completed or are scheduled to attend the other core procurement courses. The majority of the courses were classroom as opposed to correspondence courses. Out of the 768 mandatory procurement courses which were completed only 26.04 percent were taken by correspondence. If the Small Purchases Course, which is almost exclusively offered by correspondence, is eliminated, only 12.5 percent of the courses were taken by correspondence.

Several courses were identified by the respondents as being most beneficial in day-to-day procurement activities. The Defense Procurement Management Course was designated as most beneficial by 140 individuals. This was followed by 53 individuals who designated either the Defense Cost and Price Analysis or the Defense Negotiation Techniques Course.

The questionnaire asked that courses be identified for addition to or deletion from the intern program. Thirty one point ninety one (31.91) percent suggested additional courses were needed. Some 32 specific courses

TABLE VII

MIX OF CONTRACTS VS. INTERN EXPERIENCE

TYPE	DA PROCUREMENT STATISTICS % OF FY 76 ACTIONS	% OF RESPONDENTS WITH EXPERIENCE
FFP	80.0	63.0
FPE	6.0	24.7
FPI	2.0	5.6
CPAF	0.6	2.3
CPFF	7.0	18.3
CPIF	1.6	5.4
T&M	1.3	13.8
LH	0.06	6.9

TABLE VIII

ACTIONS ACCOMPLISHED

Question #2

ACTION	NO. OF INTERNS	% OF THOSE ANSWERING
Two-Step Formal Advertising	21	11.11
Partial Set-Asides	70	37.04
Competitive Negotiation over $100,000	88	46.56
Price/Cost Analysis $10,000 to $100,000	113	59.79
Price/Cost Analysis over $100,00	75	39.68
Sole Source Negotiations over $100,000	90	47.62
8(a) Contracts	29	15.34
Off-Shore Procurements	9	4.76
Small Purchases	184	97.35
Formal Advertising	158	83.60
Basic Order Agreement	88	46.56

TABLE IX

ACTIONS ACCOMPLISHED

Question #3

ACTION	# OF INTERNS	% OF THOSE ANSWERING
Protests to the General Accounting Office	28	16.67
Appeals to the Armed Services Board of Contract Appeals	30	17.86
Claims Against the Government	53	31.55
Terminations for Default	65	38.69
Terminations for Convenience	78	46.43
No Cost Terminations	75	44.64
Certificate of Competency Procedures	70	41.67
Mistakes in Bids	107	63.69
Late Bids or Proposals	122	72.62
Reprocurement after Terminations	48	28.57
Contracts with Government Furnished Property	139	82.74

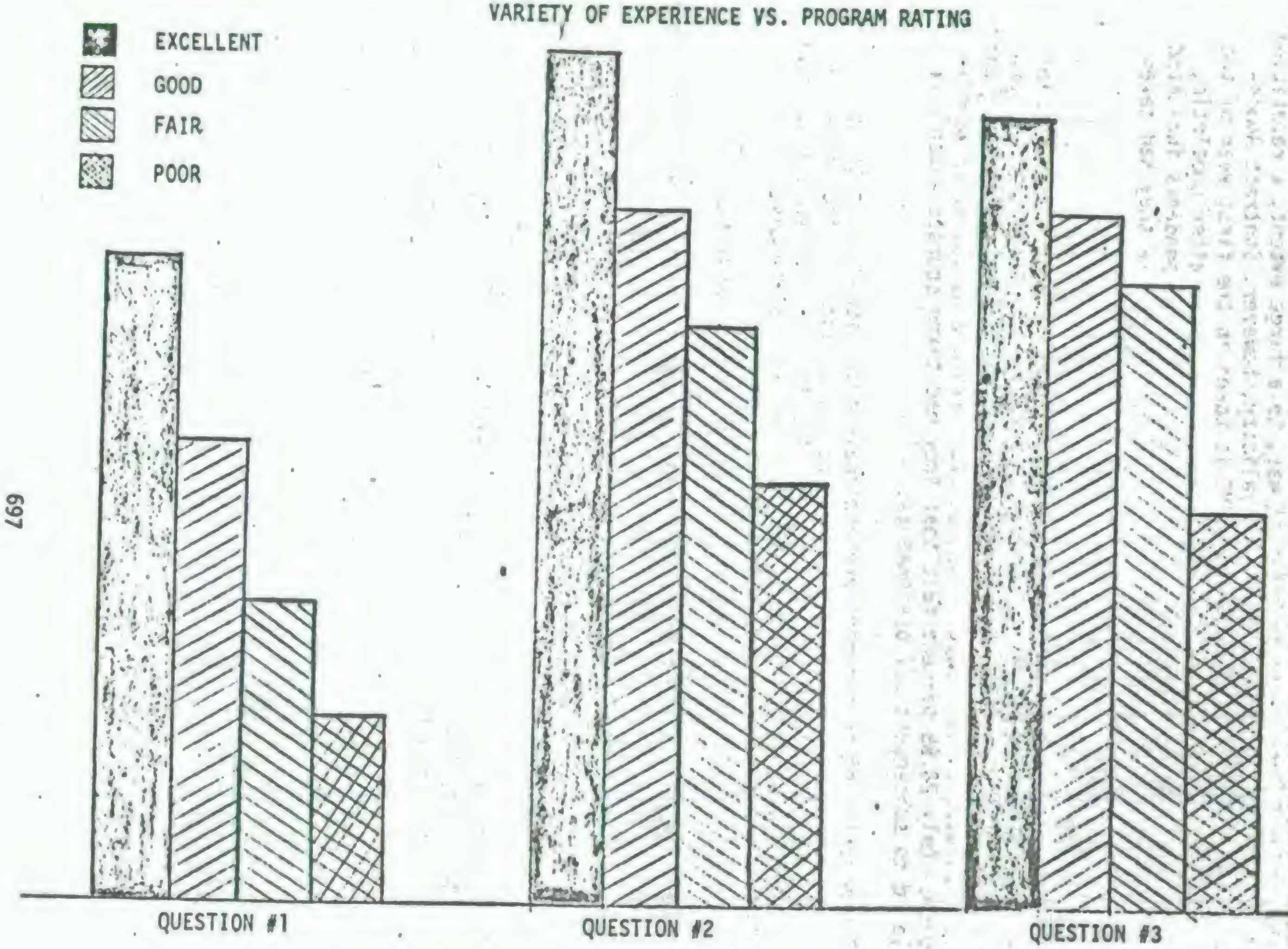

VARIETY OF EXPERIENCE VS. PROGRAM RATING
EXCELLENT
GOOD
FAIR
POOR
QUESTION #1
QUESTION #2
QUESTION #3

FIGURE 3

or topic areas were identified, however, no one course was recommended by a significant majority. Eighteen point seventy-two (18.72) percent of the sample indicated need to delete courses from the program. The most often mentioned course for deletion was the ADP seminar (10 respondents), the next most often recommended for deletion was the Contract Administration Course (8 respondents). Several of those recommending deletion of the Contract Administration Course indicated that it was, to a large extent, a repetition of DPMC. This criticism may have some validity, however, Contract Administration is a third year course and DPMC is taken in the first year of the program. A review of some DPMC subject matter two years after completing DPMC could very well be beneficial. Additionally, 27 respondents indicated that Contract Administration was the most beneficial course they had taken.

THE BRIDGE BETWEEN CLASSROOM AND OJT

The intern program is succeeding in translating what is learned in the classroom into useful, practical work experiences. Seventy-two point zero four (72.04) percent of those answering believe that classroom training was directly related to OJT assignments received within 3 months after completing a course. Only 28.65 percent felt that they had taken courses which were unrelated to subsequent OJT assignments.

The majority of procurement professionals interviewed indicated that they make a definite effort to give interns OJT assignments that relate to courses recently completed, and several stated that they often discuss course content and how it relates to new jobs the interns will be given.

There are two areas where there is a problem linking formal training to OJT. The Defense Small Purchases course is to be taken within the first 120 days of the program. This course is for the most part taken in the correspondence mode. Often the intern has completed his 320 hours of Small Purchases OJT before he completes the correspondence course. The second problem area concerned scheduling of the rotational Pricing assignment to occur soon after an intern has completed the Principles of Contract Pricing course. This is not always done.

The amount of classroom training an intern receives is related to how well he perceives the program as preparing one for journeyman level performance. Those who rated the program "excellent" had attended an average of 4.26 courses. Those who rated the program "poor" had attended an average of 3.33 courses. Those who rated the program "excellent" were also scheduled to attend more courses than those who rated the program "poor."

APPRAISING INTERN'S PERFORMANCE

As with any other employee, the intern's performance must be periodically evaluated. This evaluation is accomplished semiannually through the use of DARCOM Form 2002, Career Intern Progress Report. The purpose of the report is twofold, first to evaluate performance, and second to

ensure that the interns are receiving the necessary training assignments. This report requires that the number of hours devoted to each training subject be listed and performance evaluated on a scale of one to three: one being unsatisfactory; two, satisfactory; and three, outstanding. The report provides for written comments by both the intern and the intern's supervisor.

Fifty-five point twenty-five (55.25) percent of the interns believe that the appraisal form and procedures provide for a free and unbiased appraisal. Approximately 36 percent of the interns recommended changes to either the report itself or the procedures involved. Among the most frequent were the following:

"A wider scale is needed in rating performance." (17 individuals)

"The intern's comments should be submitted separately from the supervisor's comments." (11 individuals)

"There is a need for specific guidelines in assigning ratings." (8 individuals)

"The number of hours an intern devotes to a training area should not be listed." (8 individuals)

Several comments were diametrically opposed. For instance, some individuals stated that there is no need for a comments section in the evaluation, while others stated that there should be only a comments section. One individual indicated that the grades received in formal schools training should be noted on the report. Another stated that the report should be made a part of the employee's permanent personnel folder.

MOBILITY

As indicated previously, the interns spend two years at an initial training site and then move to a permanent duty location (PDL) for the third year of training and permanent assignment. Forty-two point zero two (42.02) percent of the respondents felt that this was a necessary part of the program. Often made comments on mobility included -

"Mobility gives one a broad understanding of procurement." (20 respondents)

"Each MSC is different and one must learn new ways at each MSC." (10 respondents)

"The mobility requirement is not uniformly enforced." (8 respondents)

"Early notice of the PDL is not being given." (8 respondents)

"Mobility prepares an intern for future managerial positions or shows a serious commitment to the job." (7 respondents)

In the field interviews, some lack of enthusiasm for training interns who will be leaving in two years was detected. However, it was not widespread enough to require eliminating the mobility requirement. Several individuals did express a desire to retain good interns at the initial training site. These same individuals were also very well pleased with the third year and graduate interns with whom they had worked.

WHAT DO THE INTERNS THINK OF THE PROGRAM?

Of those answering the question "How well does the intern program prepare one for journeyman level performance?", 18.58 percent rated the program "excellent." The majority, 57.38 percent, rated the program "good." Twenty point seventy-seven (20.77) percent rated the program "fair" and only 3.28 percent rated the program "poor." The longer one was in the intern program, the better he rated the program. None of the graduate interns rated the program less than "good" and none of the third year interns rated the program less than "fair."

Comments on the program were generally complimentary. Again, some comments were diametrically opposed. Four individuals indicated that more rotational assignments are needed, while seven individuals stated that there should be fewer rotational assignments. The major complaint (28 respondents) was that the program of instruction detailing the rotational OJT and formal schools training, was not followed. Related to this question is the observation of 20 respondents that all levels of the MSC's need to know more about the Procurement Intern Program. This is especially critical at the first line supervisor's level. Other frequently made comments included:

"Interns need more work than they are currently assigned." (9 respondents)

"Interns need more challenging work than is currently assigned." (11 respondents)

"The Procurement Intern Coordinator's position at each MSC should be staffed full time by a procurement careerist." (11 respondents)

"Better scheduling of rotational assignments or formal schools training is required." (19 respondents)

Overall, the interns are pleased with the program. They feel that they are given more than adequate training and that they will be capable of functioning as full-fledged journeymen at the end of the intern program.

WHAT DO NON-INTERNS THINK OF THE PROGRAM?

Several individuals who supervise or work with procurement interns were interviewed. Better than 90 percent of these individuals believe the program does an excellent job of preparing the interns for journeyman level performance. Only 2 percent rated the program as "fair." None perceived the program as "poor." Many of those interviewed remarked that each year the incoming interns seem to be better than the previous year's interns.

Most individuals stated that they believe the interns are given interesting and challenging OJT assignments considering the available workload. Many of those interviewed relied very heavily on the interns for accomplishment of their office's workload. Nearly all felt that the rotational OJT assignments were extremely beneficial to the intern's career. The most common criticism was that the first line supervisor was often uninformed of upcoming rotational OJT and formal schools training.

The majority of those interviewed indicated that the formal schools training given the interns is more than adequate. Several stated that the ADP Orientation Seminar is inappropirate in that the interns need an ADP orientation to the ALPHA system much more than they need a general ADP orientation.

CONCLUSIONS

1. The DARCOM Procurement Intern Program is most definitely succeeding in producing competent journeymen. Upon completion of the third year of training, the intern is capable of functioning, on his own, as a qualified procurement professional.

2. OJT rotational assignments are of the right type and are, allowing for some flexibility, of adequate length.

3. The formal schools training is, with the exception of the ADP Orientation Seminar, excellent. There is a problem with the scheduling of some interns for the Defense Small Purchases Course and the OJT/classroom connection in the Pricing area must be strengthened.

4. A valid predictor of intern intake requirements is both feasible and sorely needed.

5. First line supervisors are not always aware of an intern's upcoming rotational assignments and classroom training.

6. Increased interaction among the DARCOM Procurement Intern Coordinators would provide a transfusion of useful ideas and techniques which would continually enhance the intern program.

7. The administration of the procurement intern program requires extensive effort and a knowledge of the procurement process.

8. The current Career Intern Progress Report, while sufficient for ensuring that an intern is receiving the required training is inadequate as a performance appraisal mechanism.

9. While a diploma is presented for almost every week long course and correspondence course, no formal recognition is given to the fact that procurement interns complete a three year intensive training program.

10. A long tern study of the procurement intern program would enable HQ DARCOM to continually monitor the effectiveness of the program. It would also yield data on such things as:

a. the mortality rate in the program

b. DARCOM's return on investment in the program .

c. mobility patterns

d. career progression

RECOMMENDATIONS

1. The Automatic Data Processing Orientation Seminar should be replaced by a course which would give the interns an overview of ADP but with stress placed on the ALPHA system and the uses of ADP in Procurement. It is felt that each MSC has the necessary expertise to conduct this type of course in-house.

2. When an intern is first hired, the Directorate of Intern Training, ALMC, should initiate an enrollment request for the Defense Small Purchases Correspondence Course for that intern. This would generally ensure that an intern can complete the course piror to completion of Small Purchases OJT.

3. DARCOM Pamphlet 690-3-14, "DARCOM Civilian Training Program for Procurement Career Interns" should be revised to require that the Principles of Contract Pricing course be completed prior to an intern's OJT in the Pricing area.

4. Development of the intern requirements forecasting model should be continued.

5. Rotational assignment and classroom training schedules must be furnished both the intern and his supervisor sufficiently in advance to allow good workload planning. This is essential if the interns are to be given any type of meaningful and challenging responsibilities.

6. A meeting should be held, at least yearly, for all Procurement Intern Coordinators and HQ DARCOM, ALMC and FPO personnel connected with the procurement intern program. At this meeting problems with the program and potential improvements in the program would be discussed.

7. The administration of the procurement intern program should be the major responsibility of the Procurement Intern Coordinator. It should be part of that individual's job description and his performance appraisal should be, to a large degree, based on his efforts in this area.

8. The Career Intern Progress Report, DARCOM Form 2002, should be revised to

a. allow for a broader range in the rating scale, similar to the zero to 50 scale used on the Employee Career Appraisal, DD Form 1917 (Test)

b. provide guidelines or criteria which would be used in evaluating performance

c. require the recording of grades an intern earns in formal schools training

d. make the report a permanent part of the employee's personnel folder

9. A diploma should be awarded an intern upon completion of the program.

10. A long term study of the procurement intern program should be initiated. By developing detailed profiles and then tracking a sample of each year's intern intake the procurement intern program can be constantly improved.

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PROFESSIONALISM -- HOW DO WE GET THERE FROM HERE?

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First of all, we must define it. Turning to Webster's several years ago, I was surprised by the vagueness of the definition.

> A calling in which one professes to have acquired some special knowledge used by way either of instructing, guiding or advising others or of serving them in some art or science; as the profession of arms, theology, law or medicine.

This seemed woefully insufficient for conversion to an objective. Assuming that there must be measures of professionalism or criteria that must be met before someone or some group annoints your field as a profession, I turned to the Federal Government -- it regulates almost everything and was sure to have somewhere codified what it takes to be a professional.

The Internal Revenue Service is one organization that serves an annointing role; if your field is not recognized as a profession you cannot deduct education expenses for courses that you take to maintain professional currency. Certainly there have been occasions where such deductions have been allowed by individual IRS auditors, but whenever the deductions have been disallowed and subsequently appealed, the appeals have been denied. A good example of this occurrence is the "profession of arms" included in Webster's definition -- the IRS does not recognize the "profession of arms" as a profession. It recognizes as professionals only engineers, lawyers or medical doctors who service in the military; the line officer in the Navy, the rated officer in the Air Force, and the combat arms officer in the Army are not professionals in the eyes of the IRS. How then do you get the IRS to bless your field as a profession? The answer received was that the IRS General Counsel must rule on an appeal that relates to professional status such as a deduction for education expenses. Without further comment on that situation, let's accept that as a required wicket through which we must pass.

The US Civil Service Commission was the next source counsulted because there is a large number of procurement officials in the Federal Government work force, and, assuming that they desire the professional status conferred on their counterparts in counsel or accounting, there must be some criteria. The CSC (staff personnel) stated that a profession is characterized by:

A sophisticated body of knowledge that can only be possessed by the professional and is not readily available in the form of written regulation or procedure. This must be reflected in CSC position classification standards and personnel qualification standards.

A work force that is made up of individuals possessing at least bachelor degrees with degree concentration in the professional field. However, several recent court decisions have prompted some waffling on the part of the CSC staff in this area. I asked if personnel management was considered to be a profession, and after some pondering, the CSC staff (personnel management) replied, "No." At least this response was a bit more direct than the one received from IRS.

The first criteria set forth by the CSC, "a sophisticated body of knowledge. . .," requires further comment. How do we measure this requirement? One way is to look at the degree of complexity of our field. How much of our business is performed by-the-book, where we refer to a regulation or policy document to determine how to respond to a given situation? How much regulatory or policy matter exists? Can we find the answers to most of our problems in these documents or do the answers come for judgment calls? The answers to these questions must be a matter of judgment if you consider the amount of contract litigation pending in our judicial system and the relative vagueness of many issues in our contracting policy.

The second definition requires that we have a work force where those persons of authority and responsibility possess at least a bachelor degree with concentration in the contracting field. This is a tougn requirement because only two universities offer bachelor degree programs in contracting, and many years will pass before we can generate enough demand to convince the universities that contracting programs are needed.

Another contribution to the definition of professionalism comes from Al Raisters of Hughes Aircraft, the Education Chairman of the NCMA Los Angeles South Bay Chapter. In the Summer 1976 NCMA Journal, Mr. Raisters writes:

> Another sideline of interest to N.C.M.A. should be the accepted custom that non-professional occupations deal with customers and professionals with clients. Is there a difference between customers and clients? If so, what implications may such a difference have? A customer determines what goods or services he wants to acquire and has the freedom to shop around until his needs are met. This is based on the premise that he has the capacity to appraise his needs and to make the judgement about the services provided. If the customer is not happy, he is free to criticize the commodity and even demand a refund. In the professional relationship, the client has no choice but to accept the professional's judgement, since the client has surrendered his authority to the professional. In this way, the client invests the professional with a monopoly of judgement. One of the basic characteristics of professionalism is that professionals have the tendency to acquire a monopoly of judgement.

This is an important aspect of professionalism, a matter of which we may be unaware. Are we taking away this judgmental authority by the proliferation of policy and procedure? Will we eventually have to respond with the answer "No" as did the gentleman from the Civil Service Commission when asked if personnel management was a profession? One of the reasons personnel management is not considered a profession is that it has expanded its policy and procedure to the point where judgment's role in decision making has been reduced. In the April 1977 International Personnel Management Association Newsletter, an abstract of an article by C. Mansel Keine, Vice Chancellor (retired), Faculty and Staff Affairs, The California State Univeristy and Colleges, states:

> This article advances the concept that personnel administration has been and continues to be overly mechanistic; ignores the omnipresence of the effects of human judgment; places staff too often in an adversarial relationship with management and does not go far enough in selling itself to management.

We also must consider, from our view of other professions, the need for discipline to prevent our professional status from diminishing after we have attained it. Consider the profession of law. While driving to this symposium, I observed a bumper sticker on an automobile: "DON'T HIT ME MY LAWYER'S IN JAIL." Another indication of professional degradation came from the Washington Post. In his review of one of the current books on Watergate (Stonewall by Richard Ben-Veniste and George Frampton), Robert Sherrill begins:

> Americans, in the privacy of their bruised hearts, have always had a hidden allegiance to the rite of lynching. It gets the job done without the incumbrance of lawyers.
>
> But one must discriminate. There are young lawyers, many of whom, still uncorrupted by their profession, look upon law as a system for speeding justice. And then there are the old slick-haired lawyers, who often seem to forget the difference between law and politics or law and just plain money-grubbing.

Enough about definitions. Where do we stand now, what progress have we made, and what must we do to achieve our objective of professional status?

We have made progress. The National Contract Management Association sponsored and is operating a certification program for all contracts managers. The program establishes a discipline; it holds the certified person to a code of ethics; it measures attainment of experience, education, training, and knowledge. The education requirement for certification is a bachelor degree, in any field of concentration. In the future, this requirement will change to a bachelor degree with concentration in the field of contracting. We cannot at this time require that concentration because so few universities offer contracting programs. Incidentally, the requirement that applicants possess a degree is probably our most important step toward professionalism, because it encourages the universities to establish degree programs concentrating in contracting. Given a positive response by academia to these demands, we may eventually be able to bring into the field only those persons with a degree specifically in contracting. When we have achieved that, we will be qualified in the eyes of the Internal Revenue Service and the Civil Service Commission.

As we progress toward professionalism we must keep in mind the future. The decisions we make along the way can either enhance the stature of our discipline or prevent us from being able to reject those persons who violate our code of ethics.

There is one last concern: the need to maintain the judgment factor in procurement and contracting. If your research culminates in more definitive policy and more procedure that reduces decision making or if you encourage a mechanistic approach to contracting, you will be hindering progress toward professionalism. On the other hand, if your research endeavors promote decision making causing in all instances a judgment call by the procurement official, we may someday be calling him a procurement professional.

SELECTED REMARKS ON PROCUREMENT PROFESSIONALISM

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My general theme this morning refers to need for new talent in procurement profession.

Ed Lovett has noted that 60% of Army Procurement workforce is over 50 years of age as of December, 1975 (Grades 12-15) and 35% eligible to retire by December, 1978. In other words, about one-third of the top talent in Army Procurement may retire in about one year. If this were ITT or GM you can bet they would be concerned as would be their stock holders.

I see the great need in the next two to ten years to be in the recruitment and retention of young, talented people from a wide variety of academic interests; not just Business Majors but Engineers, Operation Researchers, System Analysts, and other technical and quantitative backgrounds. I don't know Les Fettig personally but I can say that he is the type of talent to which I refer.

My so named "Selected Remarks" are addressed to this one specific problem of bringing on board this young, diversified talent and then keeping it from drifting to perhaps more lucrative or self-satisfying careers.

In my opinion, every young talent leaving college today is looking for a minimum of two attributes in his chosen profession. If either one of these attributes are lacking, the talent will tend to look elsewhere.

What are they?

The first is a well-defined and reasonably attainable program whereby he (or she) can continuously update the skills and educational level in the chosen functional field (in this case procurement or contract management.)

Secondly, and probably just as important, is a highly visible track of advancement in the profession; this includes monetary rewards, opportunities for advancement, self-satisfaction, recognition, and achievement.

For the most part, the procurement profession has not been high on the pecking order in either category in the past; although a great deal of progress is currently being made.

Compared to the more functional careers such as Finance, Medicine, Law and Engineering; the young people just don't see the same opportunities available in procurement.

For instance, how many undergraduate students do you know who took even one course relative to procurement? How many do you know who would even know what you are talking about? Damn few.

I don't believe it is because they would not be interested; but simply they are not aware.

My experience in the industrial arena (Aerospace as a Project Manager and Engineering

Director) up to about 1970 seemed to place the procurement area somewhat below the other functional areas of engineering, finance, etc. However, with the advent of Fixed Fee Contracts and incentive contracts the procurement function has rapidly gained recognition as a solid career; at least with the insiders but less so with the young talent just entering the labor market.

I'll address only one subset of the former job attributes (educational opportunities) and leave the second attribute (opportunity for advancement promotion, etc) to others.

I'll also limit my remarks to only one aspect of education - Graduate Procurement Education.

Dr. Hood has addressed aspects of job-related learning projects and Ed Lovett has discussed the DARCOM Procurement Intern Training Program. Graduate level procurement training complements these programs.

Let me briefly describe the evolution of such a graduate degree program.

In 1967 the Cape Kennedy area recognized a need for procurement training and there was virtually none available. This resulted in the FIT, in cooperation with the NCMA, establishing a certificate program in the procurement area. However, several individuals in the procurement profession expressed interest in advanced work. So, in 1968 FIT, again in cooperation with the NCMA, implemented a Master of Science degree program in Contract and Procurement Management.

At first all of the courses were in Contract/Procurement Management. This didn't make much sense; there was too much redundancy, too much overlap. We must recognize that first we must be a professional, effective manager and then a functional specialist, a procurement professional. With this in mind the curriculum was changed to include traditional Business/Management courses:

Economics
Finance
Accounting
Behavioral Science
MIS
Organization Development

Plus strong concentration in Contract & Procurement Management.

Most of these are probably familiar to you.

Basic Contract Management and Administration
Contract Changes, Terminations and Disputes
Cost Principals
Contract and Sub-contract Formation
Contract Negotiation and Incentive Contracts
Research Seminar
Contract Management

Plus three electives in Contract Management or Business.

We tend to modify the curriculum as needs change but the mix of contract management/business courses stays pretty much the same!

Incidentally, we've had good results in offering an Undergraduate course in Procurement to our engineering students but have less success in developing an Undergraduate Program in this field.

I've more or less covered the "well-defined" aspect of the Educational need, since this graduate program has evolved over about ten years to a substantially highly structured program.

But is it "reasonably available?" Yes and No. Graduate offerings in the procurement field are not commonplace. One method of delivery which I feel that FIT has had a great deal of success in is in the implementation of off-campus programs, as cooperative efforts with such institutions as Army Logistics Management Center, Army Management Engineering Training Agency, and the Transportation School.

These have much to offer - unlike our science and engineering programs, there is no real need for elaborate laboratories. The offerings occur in centers of high interest and exceptional talent. We have a number of real advantages in these offerings:

1) They are more readily accessible to a larger body of students who cannot afford the year required to attend at campus.

2) Availability of exceptional talent (Practitioners) for instruction in the unique procurement courses; for instance, Dr. Arvis at Ft Lee in the research course. Who could do a better job?

3) A closeness to the real world of procurement and its problems, changes and requirements. A built-in awareness.

4) A blend or mixture of both students and faculty from all sides of the house:

Industry
Government
Civil Service
Military
NASA
Universities

I feel that the graduate of these programs benefits by such contact and ends up with a far broader picture of the entire procurement process thru the day-to-day contact in a non-adversary atmosphere.

In summary; I see two attributes to be met in the Procurement field in order to attract and retain young talent; (1) well defined and reasonably available education and (2) a highly visible promotional path.

I've described the evolution of one aspect of the educational program - graduate level education. I've identified one successful approach to make this education "reasonably available" and I've noted a few of the more evident advantages of such a program.

There are many other approaches to this problem I'm sure, but my experience at this time reinforces my opinion that graduate level procurement training is greatly in demand and can be delivered effectively by our university system.

CONCLUDING REMARKS

John H. Kunsemiller
Chairman, DOD Procurement
Research Coordinating Committee

DOD is big business - we need research. There is nothing so useless as doing things with great energy and efficiency which should not be done at all. That is probably the greatest pitfall we must avoid, both in management and in the research business. Does this then mean that every research project must have an immediate and total payoff? Quite obviously the answer is a resounding no. A research project which identifies a "dead-end" has value. To keep ahead of the proverbial power curve we must have a mix of projects that are of the problem solving type and from which we can expect an immediate payoff as well as long range efforts which are primarily design as thought-producing in today's environment. The acquisition process, and that is what I think procurement research is all about, is an extremely dynamic process that is continually affected by Congressional action, executive directives, and the economy as well as the socio-economic and geo-political situation on a world-wide basis. We have but to look at the F-16 program with its international implications to realize what effect Geo-Politics can have on the acquisition process. Thus, our program must be a mixture of the applied as well as theoretical research. However, it is well for us to be constantly aware that our first priority is to be responsive to the requests of our customers. You have been challenged with new thoughts or new slants on old ideas - research must respond.

As Chairman of the Procurement Research Coordinating Committee and through my overall involvement in the procurement research program, I have had the pleasure of meeting most of our full time research staffers and many these past few days. From my observations I have concluded that we have an extremely talented group who not only understand, but of even greater significance have a strong feeling for the acquisition process. However, the success of our program needs more than able people ably led if it is to be effective. The one additional ingredient I'm talking about is the method you choose to present your results. Your clients will be functional managers and these individuals are, for the most part, not research specialists. Consequently, the product they rightly expect is one that tells them in laymen's terms what your recommendations are, how and why you arrived at your conclusions, and how your recommendations derive therefrom. I'm sure you operating managers will agree with me that there is nothing more boring than opening a report that is loaded with mathematical formulas, theorems, hypotheses, etc., that have meaning only to someone else in a specific field of research. Skepticism is the natural result and a communications barrier is built up. He probably won't look beyond the technical data. In making this statement I am fully aware that operations research tools form the basis for many of your conclusions. This is good but what I am really asking you to do is to place yourselves in the functional manager's position when the report is prepared. Sectionalize the report, if you will, but give him a clear story that can be understood in his terminology.

Glamour - be it on the hoof or in procurement always draws attention. Then it is no wonder that so much of our procurement research has centered on all phases of the acquisition of weapon systems. Let's face it - these are the glamorous procurements. However, it is well for us to remember that the cost of supporting the weapon system throughout its life far exceeds the acquisition cost. It goes without saying also that readiness of the weapon to perform is indirectly proportional to the types of logistics support we are able to provide. We have had some procurement research in this area but it needs more attention.

Then there is the matter of base support services that must be performed to keep the installation going. In the repair contracts area there are problems with types of contracts, spare parts support, outdated tech orders, to say nothing of specifications and such terms as over and above work. The base support services are highly competitive and therefore, we face daily the problem of "buying in." Also, in this area we have our greatest concentration of socio-economic related contracting and more particularly contracts awarded under Section 8(a) of the Small Business Act. A question I would like to pose to you on this subject is this. What are our responsibilities towards making the 8(a) contractor more vital and competitive in the future?

In developing specifications for total contractor operation of a base, can we break out the major functions into economical packages giving small business a continuing opportunity to bid? Or must we go the single total package route and justify this approach totally on the basis of economy. Surely the answer must be somewhere in between the two extremes.

I bring these matters up because of our stickiest problems in procurement rear their heads in the weapon and base maintenance and support service contracts.

Ladies and Gentlemen, all I am trying to say to you is look over the entire spectrum of our procurement operation for research projects and not just the glamour programs. The rewards and payoffs from a job well done are there.

Each of the service research components have some good examples of procurement research performed in both the glamorous and not so glamorous area. For example, the Army finished a study which identifies recurring RFP problems and developed a procedure for constructing RFP's to provide for simplicity, uniformity and clarity. The Air Force recently completed an Engine Cost Modeling Study which analyzed the existing approach to predicting aircraft jet engine costs. Individual faculty members at the Naval Postgraduate School (NPS) have made significant individual contributions in Project Management, warranties and inflation. These are good examples of what is going on. To those of you who are not directly tied into our research effort, I ask you to talk to our researchers and let's continue - renew the cross-fertilization of ideas. When we have a common understanding of the problems, we can harness the tremendous potential which you represent toward achieving a solution. The Procurement Managers must be involved with research - "research is too important to be left only to researchers."

How can we tell the world, or just tell the boss how good we are? Our OSD Directive calls for an annual summary of the procurement research effort with quarterly updates. The Defense Logistics Studies Information Exchange (DLSIE) is the source since each research project is to be initially reported and updated. Therefore, summaries are already included in their computerized system. But be sure that each of you logs in with DLSIE.

In any case, we need a vehicle to "tell and sell" top management on what is going on. Unfortunately, I don't have the complete answer. In fact, it's up to each of you to "tell and sell." You can bet your bottom dollar that this is an item we in DOD will push and push hard at future PRCC meetings until we do come up with an answer. I consider this crucial to the continued health of the DOD Procurement Research Program. As the FPI becomes a fact, we can look for an assist in this area. Other people are helping too. Keep yourself informed - tap into the results.

At Thursday's luncheon, the National Contract Management Association, which has done much to promote development of a body of procurement literature, made their annual awards for the top procurement research projects. We thank NCMA for their interest and assistance.

I want to recognize Dr. Paul Arvis and MAJ Place for the outstanding organization and support of this conference.

The 7th Annual Symposium will be hosted by the Air Force - May/June. Time and place to be announced. There will be a call for papers in Nov/Dec.

I thank you for attending and hope you enjoyed the program.

Have a safe trip home.

NCMA AWARDS

NCMA AWARDS FOR BEST PAPERS

This year's NCMA awards for best papers went to the following individuals:

1st Prize - $300 - Captain Chester Rees, US Army (Enroute to Germany) "An Analysis of the Revised Rate Structure for Civilian Employee Benefits included in OMB A-76 Cost Comparisons." (Page 715).

2d Prize - $200 - Major Felix M. Fabian, Assistant Professor, Department of Economics, Geography and Management, US Air Force Academy. "Mixed Procurement and the Management of Risk." (Page 608).

3rd Prize (Tie) - $50 - O.M. Sawyer, Supervisory Electronics Engineer, Naval Electronics Systems Engineering Center. "The Procurement and Management of a Government Owned/Contractor Operated (GOCO) Electronic Repair Facility." (Page 312).

3rd Prize (Tie) - $50 - Rosemary E. Howard, Equal Employment Specialist, HQ Defense Logistics Agency, Executive Directorate Contractor Employment Compliance. "The Application of Management by Objectives in the Contractor Employment Compliance Program." (Page 278).

The presentations were made at the luncheon on 23 June 1977 where Mr. Jack O'Leary, Executive Director, NCMA, personally gave out the awards.

AN ANALYSIS OF THE REVISED RATE STRUCTURE FOR CIVILIAN EMPLOYEE BENEFITS INCLUDED IN OMB A-76 COST COMPARISONS

Captain Chester L. Rees, Jr.
United States Army
(En route to Korea)

INTRODUCTION

THE PROBLEM

It is federal procurement policy to rely on the private sector for needed goods and services, or to contract out versus retention in-house. This policy was implemented in 1966 and subsequently revised in 1967 by Office of Management and Budget Circular A-76 which also provided for five exceptions to the general policy. The last of these exceptions, "Procurement of the product or service from a commercial source will result in higher cost to the government,"[1] has been the most controversial, and charges by industry that the cost exception has been abused by biased cost comparisons have provoked recent analyses of the OMB A-76 program.

The cost of commercial performance can be established by contract bid or proposal primarily, but government costs must be developed from less specific cost data. Circular A-76 states that government costs must include: "all elements of compensation and allowances for both military and civilian personnel, including the full cost to the government of retirement systems, calculated on a normal cost basis."[2] Accordingly, DOD Instruction 4100.33 and AR 235-5, which further implement OMB A-76 with cost comparison methods, list the government's contribution for civilian retirement and disability, health, and insurance as a percentage of the base pay to be included in the labor rates for in-house costing. It is widely recognized that the actual cost to the government is substantially higher than the current figure of 7% used for retirement. The discrepancy results from the fact that government contributions for retirement and other benefits are based on a static projection of cost to the system which does not take into account future pay and benefit increases. The Civil Service Commission was therefore tasked to develop new benefit cost to the government based on dynamic rather than static normal costs.[3] The Office of Federal Procurement Policy published the new figures in a memorandum on 23 August 1976 which asked for comments from affected agencies. Department of Defense issued a subsequent directive on 27 August 1976 calling for immediate implementation of the revised rates on cost comparisons submitted after the new fiscal year on 1 October 1976. The new cost figures are shown in Table 1. Since labor costs are a significant element of any cost analysis, a substantial increase in in-house cost estimates can be expected.

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[1] OMB Circular A-76, Revised August 30, 1967, para. 5.
[2] Ibid., para 7.
[3] Office of Federal Procurement Policy. "Cost Comparisons Under OMB Circular A-76," Federal Register, August 23, 1976, p. 35581.

TABLE I

CIVILIAN BENEFIT RATES

	Old[4]	New[5]
Retirement & Disability	7.14%	24.7%
Health Insurance	1.0%	3.5%
Life Insurance	.3%	.5%
TOTALS	8.44%	28.7%

PURPOSE OF INVESTIGATION

The purpose of this investigation is to determine the extent to which recent cost comparisons will be altered by application of the revised civilian employee benefit rates. The probable effect of the revised rates on future cost comparisons and the resulting in-house or contract out decisions will also be determined.

HYPOTHESIS

The hypothesis to be tested is that the application of the revised, more realistic costs of civilian government employees' fringe benefits to previous U.S. Army cost comparisons will indicate that a significant number of decisions would have been reversed in favor of contracting out.

SIGNIFICANCE OF RESEARCH

Cost comparisons are used to base decisions for in-house performance from one to three years; at the end of which time a renewal cost comparison must be conducted to justify further in-house retention. Since there are relatively few new in-house starts each year as opposed to renewals of existing programs, the preponderance of future cost comparisons will be conducted on programs already in existence which are the target of this study. This research project should provide a basis for future personnel planning based on the number of expected reversals of current in-house programs in favor of contracting out.

Also this study should enable agency planners to specifically identify individual cost comparisons which may become more costly on the in-house side than the contract side. If a simple decision rule could be established for identifying which CITA functions would probably be affected, another problem could be solved. The problem has derived from a July 27, 1976 OMB memorandum which orders all federal agencies to identify at least five functions presently performed in-house to be contracted out to private industry.[6] With the availability of a reliable decision rule for identifying potential in-house reversals,

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[4] U.S. Army Training and Doctrine Command, TRADOC Pamphlet 235-5 Cost Analysis Worksheet, Fort Monroe, VA: October, 1973, pp. 4-5.

[5] Assistant Secretary of Defense (I&L) Memorandum, Subject: "Revised Rate Structure for DOD Instruction 4100.33, August 27, 1976, p.1.

[6] "Ford Orders More Contracting-Out", Federal Times, August 23, 1976, 12: 1, 16.p.1.

the agencies could satisfy the requirement without going through the time consuming process of applying the revised rates to each of their current cost comparisons.

METHODOLOGY

Test data for this study has been acquired from a sample of 43 cost comparisons from DARCOM (28) and TRADOC (15) Commercial-Industrial Type Activity (CITA) Offices. The sample was taken from cost comparisons from FY 74, 75, and 76. All cost comparisons used to draw the sample had been audited by the Army Audit Agency and approved by the command's CITA office as opposed to many which had been submitted without approval to date. This should insure that the sample will include the most accurate data on which to base the findings of this report. The sample cost comparisons will be analyzed using the new 28.7% benefit rate as opposed to the old 8.44% to determine if a substantial number of decisions would have been reversed in favor of contracting out. A "t" Test for significance will then be used to determine the statistical significance of the mean value for in-house costs before and after the revision. If the sample does indicate that there will be a significant number of reversals for future cost comparison decisions, this study will also examine the validity of the revised rates.

EXPECTED RESULTS

It is expected that this studywill show that there will be an increase in future contracting out decisions by the Army based on analysis of past cost comparisons. This will mean a decrease in the number of in-house programs, and, consequently, a decrease in government employed civilian manpower.

ANALYSIS

SAMPLING TECHNIQUE

Three major commands, DARCOM, TRADOC, and FORSCOM, have the majority of the responsibility for approving and maintaining U.S. Army CITA cost comparisons within the Continental United States. This study makes the assumption that samples taken from two of these major commands, DARCOM and TRADOC, will be representative of the population of cost comparisons within the Army. Also, taking samples from at least two commands will provide a means of insuring that the sample will be representative since the sample results of the two commands could be compared to check their validity.

The initial step in identifying a sample was to identify all cost comparisons (Code D) which had been approved and audited as listed in the Inventory of C-I Functions and Contract Support Services FY 76. Then a random sample was taken proportionate to the number which had been approved during a particular fiscal year.[7] Out of 52 originally identified at TRADOC (14 - FY 74; 26 - FY 75; 12 - FY 76), 15 were chosen for the sample (4 - FY 74; 6 - FY 75; 5 - FY 76). Out of 65 originally identified at DARCOM (59 - FY 76; 6 - FY 75) 28 were chosen for the sample (25 - FY 76; 3 - FY 75). Data from the files of the sample CITA functions is included in Appendixes A and B. The data for contractor cost, government cost, and civilian personnel cost, was obtained from lines 9A, 20A, and 11 respectively, of the Cost Comparison Worksheets DA Form 3207-R, an example of which can be found in Exhibit A.

Several inconsistencies in the sample need to be explained at this point. First, the majority of the samples taken from DARCOM were approved in FY 76 as opposed to TRADOC's

[7]This study is based on data originally collected as part of a research project conducted as a requirement for a Master Science degree program.

sample which had a more even distribution over the past three years. This was explained by the fact that DARCOM had increased its surveillance of the cost comparisons, requiring most to be renewed during the past fiscal year.[8]

A second inconsistency can be found in several instances where the costs listed on some cost comparison worksheets remain the same for four years while others increase from year to year. An example of this difference can be seen by examining DARCOM samples number 6 (Redstone Arsenal T 801) and number 1 (Savanna Army Depot S 724). The explanation for this occurrence is that while AR 235-5 does provide for escalation of costs year to year based on inflationary trends, it is not required in order for the cost comparison to be approved.[9]

A final inconsistency can be found in DARCOM sample number 27 (Savanna Army Depot T 812) where the decision was made to retain the function in-house even though total in-house costs are more than contracting-out costs. It is evident, however, that first year start up costs for the government were the primary cause, and if the analysis were carried over to a fifth year, the government's savings of over $60,000 per year would reverse the totals in favor of retaining in-house.[10]

Once the data had been collected the next step involved adjusting the civilian personnel costs and the total government costs by the revised fringe benefits rates. As an example, the data from the first year of the cost comparison worksheet at Exhibit A is tabulated in Table 2.

TABLE 2

COMPUTING NEW CIVILIAN PERSONNEL COSTS

Civilian Personnel Cost	448,421 ÷ 1,0844 = 413,520
New Civilian Personnel Cost	413,520 x 1.287 = 532,200
Government Cost	1,875,162 - 448,421 = 1,426,741
New Government Cost	1,426,741 [illegible] ,200 = 1,958.941

PRELIMINARY RESULTS

Once the new fringe benefit rates had been added into all of the sample cost comparisons, the initial findings were that the costs of two of the TRADOC samples (Ft. Benning W 826 and Ft. Lee W 824/826) and six of the DARCOM samples (Sacramento Army Depot S 724, Letterkenny Army Depot T 801 and T817, Picatinny Arsenal X 931, Tobyhanna Army Depot T 801, Fort Monmouth S 714) had reversed indicating that contracting-out would be less costly to the government. Savanna Army Depot T 812, remained more costly in-house; however, it is assumed that since the sunk costs incurred during the first year are already spent, that the decision would be to continue the function in-house due to the $53,000 per year savings. Following the same reasoning, two other functions which had total contractor costs

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[8]Weaver, Mrs. Alma, CITA Coordinator, Installations and Services Directorate, Headquarters, DARCOM, Washington DC, Interview 6 October 1976.
[9]Ibid.
[10]Ibid.

exceeding total government costs but with substantially higher government costs during the second through fourth years were observed (Fort Sill J 512, Picatinny Arsenal T 801). It is therefore determined that these two cost comparisons descisions would be reversed in favor of contracting-out.

This makes a total of 10 of the 43 sampled CITA functions that should revert to the private sector for performance under the revised benefit rate structure.

PROPORTION TESTS[11]

At this point of the study it is important to check the difference in the TRADOC sample and the DARCOM sample to determine if their relative change varies significantly. TRADOC had three probable decision reversals, or 20% of the 15 total sampled cases, and DARCOM had 7 decision reversals, or 23% of the 28 total sampled cases. The difference in the percent of reversals is small, and a slightly higher percentage of reversals at DARCOM might be explained by the fact that the majority of the sampled cases are from FY 76 and therefore subject to increased surveillance and closer auditing procedures. To determine if there is statistical significance in the difference between the 23% and the 20% reversals for the two samples, a proportion test can be used.

$$H_o : P_D = P_T$$

$$\frac{\left(P_D - P_T\right) - \left(P_D - P_T\right)}{\sqrt{\frac{P_D q_D}{n_D} + \frac{P_T q_T}{n_T}}} = \frac{\left(\frac{7}{28} - \frac{3}{15}\right) - 0}{\sqrt{\frac{\frac{7}{28} \cdot \frac{21}{28}}{23} + \frac{\frac{3}{15} \cdot \frac{12}{15}}{15}}} = \frac{.05}{.59} = .08$$

$\therefore$ Do not reject H_o

The difference in the means of the government costs of the two samples can also be analyzed to determine if there is any statistical difference. The TRADOC mean cost rose from $1,713,950 to $1,906,375 or 11% increase with the application of the new rates. The DARCOM mean cost rose from $4,892,309 to $5,687,697 or 16% and the overall $430 mean cost rose from $3,783,579 to $4,368,631 or 15%. A two mean proportion test can also be used to determine if there is any statistical significance in the two increases of 11% and 16%.

$$H_o : P_D = P_T$$

$$\frac{\left(P_D - P_T\right) - \left(P_D - P_T\right)}{\sqrt{\frac{P_D q_D}{n_D} + \frac{P_T q_T}{n_T}}} = \frac{(.16 - .11) - 0}{\sqrt{\frac{(.16)\,(.84)}{28} + \frac{(.11)\,(.89)}{13}}} = \frac{.05}{.106} = .47$$

$\therefore$ Do not reject H_o

[11]Dr. Allen Sanderson, College of William and Mary, Economics edpartment is recognized for his assistance in making statistical analyses used to support the findings.

On the basis of these two proportion tests it is therefore concluded that the two independent samples at DARCOM and TRADOC are not statistically significant in their differences, and further analysis will include data from both samples combined into one sample of 43 cost comparisons.

Out of 43 sample cases, then, a total of 10 would have reversed in-house decisions. At first observation, 10 out of 43, or 23%, appears to be a significant proportion, and to test this significance a one-mean proportion test will be used. The null hypothesis in this test will be that 10 reversals is no more significant than zero reversals or:

$$H_o : P_o = 0$$

$$H_A : P_o \neq 0$$

$$= \frac{P - P_o}{\sqrt{\frac{P_q}{n}}} = \frac{\frac{10}{43} - 0}{\sqrt{\frac{\frac{10}{43}\;\frac{33}{43}}{43}}} = 3.61$$

∴ Reject H_o and accept H_A - with more than 99% assurance that $\frac{10}{43}$ is significant.

Based on this sample there is statistical significance in the number of in-house functions that would have become more costly to the government to retain in-house than if the function was performed by the private sector, and thus, the hypothesis of this study is proved true.

PAIR DIFFERENCE SIGNIFICANCE TESTS

While this last proportion test does prove that 10 out of 43 is a significant number of reversals, it does not give much statistical basis to predict any number of reversals for total of the U. S. Army. By comparing government costs before and after application of the new benefit rates through means of pair difference tests, some prediction can be made as to which cost comparisons will reflect higher in-house costs than contractor costs.

$$\bar{x}_{diff} = \bar{d} = \frac{\sum_{i=1}^{43} d_i}{43} = \frac{23303}{43} = 541.93$$

$$s_d = \sqrt{\frac{\sum(d_i - \bar{d})^2}{n-1}} = \sqrt{\frac{57,120,171}{42}} = 1166.2$$

Taking the data compiled in Table 3, the significance of the difference in means before and after the revised benefit rates were used can be analyzed. The null hypothesis in this case will propose that there is no significance to the difference in government costs before and after the revised benefit rates have been applied.

TABLE 3

Pair Difference Of In-House Costs (in thousands)

n	With Revised Rates	Without Revised Rates	diff	$(d_i - \bar{d})$	$(d_i - \bar{d})^2$
1	4,725	4,191	534	8	64
2	1,137	1,005	132	410	168,100
3	443	385	58	484	234,256
4	595	532	63	479	229,441
5	2,364	2,173	191	351	123,301
6	708	617	91	451	203,401
7	973	856	117	425	180,625
8	1,308	1,110	198	344	118,336
9	5,544	4,811	733	191	36,481
10	1,573	1,480	93	449	201,601
11	1,675	1,454	222	320	202,400
12	473	401	72	470	220,900
13	1,669	1,560	109	433	187,489
14	3,347	3,084	263	279	77,841
15	2,059	1,902	157	385	148,225
16	2,147	1,863	284	258	66,564
17	2,097	1,826	271	271	73,441
18	2,413	2,071	342	200	40,000
19	17,669	15,694	1,975	1,433	2,053,489
20	3,078	2,926	152	390	152,100

n	With Revised Rates	Without Revised Rates	diff	$(d_i - \bar{d})$	$(d_i - \bar{d})^2$
21	477	405	72	470	220,900
22	194	165	29	513	263,169
23	215	183	32	310	260,100
24	46,285	39,994	6,291	5,749	33,051,001
25	6,431	5,926	305	37	1,369
26	397	535	62	480	230,400
27	1,892	1,754	138	404	163,216
28	587	599	88	454	206,116
29.	263	230	33	509	259.081
30	3,165	2,795	370	172	29,584
31	22,581	19,657	2,924	2,382	5,673,924
32	25,336	21,936	3,400	2,858	8,168,164
33	223	189	34	508	258,064
34	11,464	9,733	1,731	1,279	1,635,841
35	732	621	111	431	185,761
36	7,419	6,395	1,024	482	232,324
37	125	114	11	531	281,961
38	269	238	31	511	261,121
39	741	660	181	361	130,321
40	259	220	39	503	253,009
41	454	393	61	481	231,361
42	829	774	55	487	237,169
43	213	189	24	518	268,324
			23,303		57,120,171

TABLE 4

Percentage Pair Difference of In-House Costs

n	% diff (d_i)	$(d_i-\bar{d})^2$	n	% diff (d_i)	$(d_i-\bar{d})^2$
1	12.7	4.9	23	17.5	17.8[illegible]
2	13.1	.09	24	15.7	5.[illegible]
3	15.0	2.56	25	8.5	24.01
4	11.8	2.56	26	11.6	3.24
5	8.7	22.09	27	7.9	30.25
6	14.7	1.69	28	17.6	17.64
7	13.7	.09	29	14.3	.81
8	17.8	19.36	30	13.2	.04
9	15.2	3.24	31	14.9	2.25
10	6.3	50.41	32	15.5	4.41
11	13.2	.04	33	18.0	21.16
12	17.9	20.25	34	17.8	19.36
13	7.0	40.96	35	17.9	20.25
14	8.5	24.01	36	16.0	6.76
15	8.2	27.04	37	9.6	14.44
16	15.2	3.24	38	13.0	.04
17	14.8	1.96	39	12.3	1.21
18	16.5	10.24	40	17.7	18.49
19	12.6	.64	41	15.5	4.41
20	5.2	67.24	42	7.1	39.69
21	17.8	19.36	43	12.7	.49
22	17.5	16.81			
				577.7	589.83

$H_o : \mu_{new} = \mu_{old}$

$H_A : \mu_{new} > \mu_{old}$

$$t = \frac{\bar{d} - 0}{s_d / \sqrt{n}} = \frac{542}{1166.2 / \sqrt{43}} = \frac{3554}{1166.02} = 3.05$$

$\therefore$ Reject H_o and accept H_A with more than 99% assurance that there is a significant difference in mean government costs before and after the revised rates are applied.

Another pair difference test can be used to determine the average percentage increase in in-house costs and the significance this increase may have.

From Table 4 the standard deviation for the percentage rise in government cost can be computed as:

$$s_d = \sqrt{\frac{\sum (d_i - \bar{d})^2}{n-1}} = \sqrt{\frac{589.83}{42}} = 3.75$$

As previously noted, this study has gone to great length to insure that the sample drawn was random. Assuming that it is a random sample and that the mean and standard deviation of the percentage increase in government costs approximate those of the population of U. S. Army cost comparisons, then the following predictions can be made based on Table 5:

1. If government costs are within 4.7% of contractor costs before the revised rates are applied then there is a 99% probability that government costs will exceed contractor costs after the new rates are used. Likewise, there is a 95% probability of reversal if the initial costs are within 7.3%; a 90% probability of reversal if the initial costs are within 8.6%; and an 84% probability of reversal if the initial costs are within 9.7%.

2. Conversely, if initial government costs are more than 20.26% (the maximum possible increase if all government costs are for civilian personnel) above contractor costs, then there is a 100% probability that there would be no reversal. Also, there is a 95% probability that there would be no reversal of costs if initial cost differences are more than 19.6%; a 90% probability that there would be no reversal if initial cost differences are more than 17.2%.

TABLE 5

Contractor/Government Costs - % Difference

Z	s_d	x	$\bar{d} - x$	$\bar{d} + x$	P
2.33 x	3.76 =	8.73	4.7		99%
1.645 x	3.75 =	6.17	7.3	19.6	95%
1.28 x	3.75 =	4.8	8.6	18.2	90%
1.0 x	3.75 =	3.75	9.7	17.2	84%

Another analysis can be made by grouping the sampled cost comparisons by total government costs to see if there is any significance between the number of observed reversals and the government costs. Three categories can be separated - over $2,000,000 (17); $500,000 to $2,000,000 (14; and under $500,000 (12). It is interesting to note that 7 of the observed reversals fell into the over $2,000,000 category; 2 were in the $500,000 to $2,000,000 category; and 1 was in the under $500,000 category. This observation lends to the inference that while the number of actual reversals to be expected may be small, they may occur in the higher cost CITA functions. In fact, in the sample, where government costs on all 43 cost comparisons tottalled $187,851,143, a total of $76,697,646 or 41% would actually have been contracted out using the revised rates. The greater number of reversals in high cost CITA functions might be explained by the fact that contractors submitting proposals for larger contracts have subjected their estimates to closer scrutiny since they obviously would like to get the larger contracts. This also might suggest that contractor proposals used in cost comparisons of less costly CITA functions might be only token bids in some instances.

VALIDITY OF NEW RATES

Since the revised civilian benefit rates have been determined to have a significant effect on past cost comparisons, an examination as to the validity of the new rates is in order. An analysis of the way the new rates were devised by the Civil Service Commission was published in a 23 August 1975 memorandum from Hugh Witt, then Administrator for the Office of Federal Procurement Policy.[12] The memorandum also requested interested parties to submit their views on the new rates by September 20, 1976.

Representatives Morris Udall and Christopher Dodd have requested a General Accounting Office investigation of the new rates;[13] however, the GAO has not disputed the new rates at this writing. Neither have any of the other opponents of the proposed rates offered any concrete proof as to their invalidity.

While there has been some opposition to the proposed rates by the two major government employee unions, the vast majority of over 50 comments received by the OFPP as of September 20, 1976 have been favorable.[14] It is a well accepted fact that the old rate of 8.44% was

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[12]Office of Federal Procurement Policy, "Cost Comparisons Under OMB Circular A-76," Federal Register, August 23, 1976, p. 35581.

[13]Shelia Hershaw, "Contract-Out Probe on Way," Federal Times, September 20, 1976, 12:1,6, p.1.

[14]"Contract Services: Most Comments Favor Proposed OMB A-76 Supplement Raising Government Retirement Cost Factors," Federal Contracts Report, October 4, 1976, 647, p.A-20.

unrealistically low, and this study concludes, in the absence of any evidence to the contrary, that the revised rate of 28.7% is valid.

CONCLUSIONS AND RECOMMENDATIONS

This research paper has shown that there would have been a significant number of reversals of past U. S. Army cost comparisons when revised civilian employeee benefit rates were used, thus proving the hypothesis. The fact that the total costs of 10 out of 43 sampled cost comparisons (23%) reversed in favor of contracting-out provides a basis for inferring that as many as 55 out of 240 CITA functions to be reviewed next fiscal year might be contracted-out.[15] It has also been shown that while 23% of the in-house versus contract-out decisions may be reversed, these reversals tend to be centered in the higher cost CITA functions, and may affect as much as "1" of the procurement dollar currently spent on in-house performance.

This study also provides a basis for determining which CITA functions presently justified for in-house performance by reason of being less costly to the government will be changed to performance by the private sector when the revised rates are applied. Results of a random sample indicate that if initial government and contractor costs are within 13.2% then there is a 50% probability that future cost comparisons which come up for review will be contracted-out.

It is recommended that federal agencies faced with the problem of identifying five functions currently performed in-house to be contracted-out, utilize the results of this study to determine which functions will revert to private sector performance when the new benefit rates are applied.[16] By identifying these functions, which will be contracted-out eventually when they are reviewed, the agency can thus prevent inappropriately selecting a function which should remain in-house on the basis of cost. The analysis shows that by selectively reviewing current cost comparisons with differences between government and contractor costs within 4.7%, 7.3%, 8.6%, and 9.7%, there will be a probability of 99%, 95%, 90%, and 84% respectively, that the government cost will be higher when the new rates are used.

It is also recommended that further research into cost comparisons examines a sample of FORSCOM cost comparisons to insure that the random sample used in this study is really representative of the U. S. Army cost comparisons. Future research can also be conducted on other proposed rate changes will be in the areas of inflationary cost increases on materials, military wage increases, interest, and taxes.

[15] The 240 figure assumes a constant yearly number since FY 75. FY 75 figures published in ASD (I&L Memorandum August 27, 1976.)

[16] By the time of this writing affected agencies will have already chosen the five in-house functions; however, this data should prove helpful for future quotas.

APPENDIX A[17]

TRADOC COST COMPARISON SAMPLE

1. Fort Benning W 826 Data Processing

	1st year	2d year	3d year	4th year
Contractor Cost	1,373,918	1,039,639	1,090,294	1,143,415
Government Cost	1,023,974	1,006,075	1,055,021	1,106,350
Civilian Personnel Cost	662,725	695,861	730,054	767,187
New Civilian Personnel Cost	786,543	825,870	867,163	910,522
New Government Cost	1,147,792	1,136,084	1,191,530	1,249,685

Totals (4 yrs)		
	Contractor Cost	4,647,266
	Old Government Cost	4,191,420
	New Government Cost	4,725,091

2. Fort Benning J 513 Mess Hall Equipment

	1st year	2d year	3d year	4th year
Contractor Cost	385,805	313,940	313,940	313,940
Government Cost	255,924	249,852	249,852	249,852
Civilian Personnel Cost	176,429	176,429	176,429	176,429
New Civilian Personnel Cost	209,391	209,391	209,391	209,391
New Government Cost	288,886	282,814	282,814	282,814

Totals (4 yrs)		
	Contractor Cost	1,327,625
	Old Government Cost	1,005,480
	New Government Cost	1,137,328

[17] Data gathered from TRADOC files courtesy of Mr. Paul Erickson, TRADOC CITA coordinator.

3. Fort Leavenworth S 710 Insect and Rodent Control

	1st year	2d year	3d year	4th year
Contractor Cost	139,436	123,304	129,469	135,942
Government Cost	90,940	93,353	98,020	102,922
Civilian Personnel Cost	72,100	75,705	79,490	83,465
New Civilian Personnel Cost	85,571	89,849	94,341	99,059
New Government Cost	104,411	107,497	112,871	118,516
Totals (4 yrs)	Contractor Cost		528,151	
	Old Government Cost		385,235	
	New Government Cost		443,295	

4. Fort Leavenworth S 712 Refuse Collection

	1st year	2d year	3d year	4th year
Contractor Cost	167,823	155,451	161,840	168,549
Government Cost	127,767	131,140	134,720	138,516
Civilian Personnel Cost	77,723	81,619	85,670	89,985
New Civilian Personnel Cost	92,244	96,868	101,676	106,797
New Government Cost	142,288	146,389	150,725	155,328
Totals (4 yrs)	Contractor Cost		653,663	
	Old Government Cost		532,143	
	New Government Cost		594,730	

5. Fort Leavenworth S 716 Motor Vehicle Operations

	1st year	2d year	3d year	4th year
Contractor Cost	705,957	741,254	778,316	817,232
Government Cost	552,241	507,874	553,267	559,930
Civilian Personnel Cost	237,722	249,608	262,088	275,192
New Civilian Personnel Cost	282,136	296,243	311,054	326,607
New Government Cost	596,655	554,509	602,233	611,345
Totals (4 yrs)	Contractor Cost		3,042,759	
	Old Government Cost		2,173,312	
	New Government Cost		2,364,742	

6. Fort Leavenworth — S 717 — Motor Vehicle Maintenance

	1st year	2d year	3d year	4th year
Contractor Cost	253,859	264,244	275,074	288,828
Government Cost	144,868	149,631	157,112	164,968
Civilian Personnel Cost	113,149	118,807	124,746	130,984
New Civilian Personnel Cost	134,288	141,004	148,052	155,456
New Government Cost	166,008	171,828	180,418	189,440

Totals (4 yrs)		
	Contractor Cost	1,081,985
	Old Government Cost	616,579
	New Government Cost	707,694

7. Fort Picket — J 506 — Non-Combat Vehicle Support

	1st year	2d year	3d year	4th year
Contractor Cost	414,083	345,447	345,447	345,447
Government Cost	217,887	212,598	212,598	212,598
Civilian Personnel Cost	156,775	156,775	156,775	156,775
New Civilian Personnel Cost	186,065	186,065	186,065	186,065
New Government Cost	247,177	241,888	241,888	241,888

Totals (4 yrs)		
	Contractor Cost	1,450,424
	Old Government Cost	855,681
	New Government Cost	972,841

8. Fort Sill — J 512 — Armament

	1st year	2d year	3d year	4th year
Contractor Cost	381,845	319,230	319,230	319,230
Government Cost	277,472	277,472	277,472	277,472
Civilian Personnel Cost	265,737	265,737	265,737	265,737
New Civilian Personnel Cost	315,385	315,385	315,385	315,385
New Government Cost	327,120	327,120	327,120	327,120

Totals (4 yrs)		
	Contractor Cost	1,339,535
	Old Government Cost	1,109,888
	New Government Cost	1,308,480

9. Fort Sill — S 706 — Installation Business Services

	1st year	2d year	3d year	4th year
Contractor Cost	1,631,086	1,487,472	1,487,472	1,487,472
Government Cost	1,201,758	1,201,758	1,201,758	1,201,758
Civilian Personnel Cost	986,131	986,131	986,131	986,131
New Civilian Personnel Cost	1,170,371	1,170,371	1,170,371	1,170,371
New Government Cost	1,385,998	1,385,998	1,385,998	1,385,998
Totals (4 yrs)	Contractor Cost		6,093,502	
	Old Government Cost		4,811,032	
	New Government Cost		5,543,993	

10. Fort Knox — J 512 — Armament

	1st year	2d year	3d year	4th year
Contractor Cost	698,991	497,080	497,080	497,080
Government Cost	370,015	370,015	370,015	370,015
Civilian Personnel Cost	124,444	124,444	124,444	124,444
New Civilian Personnel Cost	147,694	147,694	147,694	147,694
New Government Cost	393,265	393,265	393,265	393,265
Totals (4 yrs)	Contractor Cost		2,190,231	
	Old Government Cost		1,480,060	
	New Government Cost		1,573,060	

11. Fort Knox — J 515 — Clothing, Textiles, Canvas

	1st year	2d year	3d year	4th year
Contractor Cost	564,919	415,277	415,277	415,277
Government Cost	363,523	363,523	363,523	363,523
Civilian Personnel Cost	297,488	297,488	297,488	297,488
New Civilian Personnel Cost	353,068	353,068	353,068	353,068
New Government Cost	419,103	419,103	419,103	419,103
Totals (4 yrs)	Contractor Cost		1,810,750	
	Old Government Cost		1,454,092	
	New Government Cost		1,676,412	

12. Fort Sill   J 511   Special Equipment

	1st year	2d year	3d year	4th year
Contractor Cost	169,223	134,474	134,474	134,474
Government Cost	100,229	100,229	100,229	100,229
Civilian Personnel Cost	95,796	95,796	95,796	95,796
New Civilian Personnel Cost	113,693	113,693	113,693	113,693
New Government Cost	118,127	118,127	118,127	118,127
Totals (4 yrs)	Contractor Cost		572,655	
	Old Government Cost		400,916	
	New Government Cost		472,507	

13. Fort Knox   X 939   Rock Quarry Operation

	1st year	2d year	3d year	4th year
Contractor Cost	488,804	474,261	874,261	474,261
Government Cost	585,583	324,647	324,647	324,647
Civilian Personnel Cost	145,844	145,844	145,844	145,844
New Civilian Personnel Cost	173,092	173,092	173,092	173,092
New Government Cost	612,831	351,895	351,895	351,895
Totals (4 yrs)	Contractor Cost		1,911,587	
	Old Government Cost		1,559,524	
	New Government Cost		1,668,516	

14. Fort Lee   W 824 and W 826   Programming and Data Processing

	1st year	2d year	3d year	4th year
Contractor Cost	769,359	811,828	856,641	903,927
Government Cost	743,450	738,723	779,501	822,530
Civilian Personnel Cost	324,392	342,298	361,193	381,131
New Civilian Personnel Cost	384,999	406,250	428,675	452,888
New Government Cost	804,056	802,675	846,983	893,737
Totals (4 yrs)	Contractor Cost		3,341,755	
	Old Government Cost		3,084,204	
	New Government Cost		3,347,451	

15. Fort Belvior W 824 and W 826 Programming and Data Processing

	1st year	2d year	3d year	4th year
Contractor Cost	949,158	943,926	991,123	1,040,679
Government Cost	441,284	463,348	486,517	510,843
Civilian Personnel Cost	195,573	205,352	215,620	226,401
New Civilian Personnel Cost	232,112	243,718	255,905	268,700
New Government Cost	477,823	501,714	526,802	553,142

Totals (4 yrs)	Contractor Cost	3,924,886
	Old Government Cost	1,901,992
	New Government Cost	2,059,481

APPENDIX B[18]

DARCOM COST COMPARISON SAMPLE

1. Savanna Army Depot S 724 Guard Services

	1st year	2d year	3d year	4th year
Contractor Cost	1,155,605	1,021,408	1,072,478	1,126,101
Government Cost	432,239	453,849	476,541	500,368
Civilian Personnel Cost	352,834	370,475	388,999	408,449
New Civilian Personnel Cost	418,754	429,691	461,676	484,760
New Government Cost	498,159	523,065	549,218	576,679
Totals (4 yrs)	Contractor Cost		4,375,5[illegible]2	
	Old Government Cost		1,862,997	
	New Government Cost		2,147,121	

2. Savanna Army Depot X 945 Machine Shop Operation

	1st year	2d year	3d year	4th year
Contractor Cost	838,045	714,208	714,208	714,208
Government Cost	456,609	456,609	456,609	456,609
Civilian Personnel Cost	361,452	361,452	361,452	361,452
New Civilian Personnel Cost	428,982	428,982	428,982	428,982
New Government Cost	524,140	524,140	524,140	524,140
Totals (4 yrs)	Contractor Cost		2,980,669	
	Old Government Cost		1,826,436	
	New Government Cost		2,096,558	

[18] Data gathered form DARCOM files courtesy of Mrs. Alma Weaver, DARCOM CITA coordinator.

3. Sacramento Army Depot — S 724 Guard Services

	1st year	2d year	3d year	4th year
Contractor Cost	527,729	516,361	541,256	567,395
Government Cost	480,959	504,682	529,666	555,899
Civilian Personnel Cost	423,841	445,033	467,285	490,649
New Civilian Personnel Cost	503,028	528,179	554,589	582,318
New Government Cost	560,146	587,828	616,969	647,568
Totals (4 yrs)	Contractor Cost		2,152,741	
	Old Government Cost		2,071,206	
	New Government Cost		2,412,511	

4. Sacramento Army Depot — T 801 Packing and Crating

	1st yerr	2d year	3d year	4th year
Contractor Cost	6,290.640	5,297,610	5,562,491	5,840,616
Government Cost	3,641,092	3,823,239	4,014,413	4,215,133
Civilian Personnel Cost	2,452,219	2,574,830	2,703,572	2,838,751
New Civilian Personnel Cost	2,910,370	3,055,889	3,208,684	3,369,119
New Government Cost	4,099,243	4,304,308	4,519,525	4,745,501
Totals (4 yrs)	Contractor Cost		22,992,357	
	Old Government Cost		15,693,887	
	New Government Cost		17,668,576	

5. Yuma Proving Ground — S 724 Guard Services

	1st year	2d year	3d year	4th year
Contractor Cost	866,462	966,582	1,014,911	1,065,656
Government Cost	684,472	720,410	756,430	794,252
Civilian Personnel Cost	151,734	159,320	167,286	175,650
New Civilian Personnel Cost	180,083	189,086	198,540	208,467
New Government Cost	712,821	750,176	787,684	827,069
Totals (4 yrs)	Contractor Cost		3,913,611	
	Old Government Cost		2,925,564	
	New Government Cost		3,077,750	

6. Redstone Arsenal T 801 Packing and Crating

	1st year	2d year	3d year	4th year
Contractor Cost	166,264	166,264	166,264	166,264
Government Cost	101,313	101,313	101,313	101,313
Civilian Personnel Cost	96,177	96,177	96,177	96,177
New Civilian Personnel Cost	114,146	114,146	114,146	114,146
New Government Cost	119,282	119,282	119,282	119,282
Totals (4 yrs)	Contractor Cost		665,056	
	Old Government Cost		405,252	
	New Government Cost		477,128	

7. Redstone Arsenal T 814 Fueling Service

	1st year	2d year	3d year	4th year
Contractor Cost	68,945	68,945	68,945	68,945
Government Cost	41,243	41,243	41,243	41,243
Civilian Personnel Cost	39,096	39,096	39,096	39,096
New Civilian Personnel Cost	46,400	46,400	46,400	46,400
New Government Cost	48,547	48,547	48,547	48,547
Totals (4 yrs)	Contractor Cost		275,780	
	Old Government Cost		164,972	
	New Government Cost		194,139	

8. Redstone Arsenal T 805 Operation of Bulk Liquid Storage

	1st year	2d year	3d year	4th year
Contractor Cost	79,908	79,908	79,908	79,908
Government Cost	45,651	45,651	45,651	45,651
Civilian Personnel Cost	43,418	43,418	43,418	43,418
New Civilian Personnel Cost	51,530	51,530	51,530	51,530
New Government Cost	53,763	53,763	53,763	53,763
Totals (4 yrs)	Contractor Cost		319,632	
	Old Government Cost		182,604	
	New Government Cost		215,052	

9. DARCOM Auto. Log. Mgt. Sys. Agency W 826 Programming Services

	1st year	2d year	3d year	4th year
Contractor Cost	20,355,859	19,111,873	20,067,466	21,070,839
Government Cost	9,279,072	9,743,026	10,230,177	10,741,685
Civilian Personnel Cost	7,812,662	8,203,295	8,613,460	9,044,133
New Civilian Personnel Cost	9,272,312	9,735,928	10,222,724	10,733,861
New Government Cost	10,738,722	11,275,659	11,839,441	12,431,413
Totals (4 yrs)	Contractor Cost		80,606,037	
	Old Government Cost		39,993,960	
	New Government Cost		46,285,235	

10. DARCOM Auto. Log. Mgt. Sys. Agency W 824 Data Processing

	1st year	2d year	3d year	4th year
Contractor Cost	4,197,864	4,233,399	4,447,695	4,670,956
Government Cost	1,630,083	1,362,801	1,430,943	1,502,489
Civilian Personnel Cost	626,427	657,748	690,635	725,167
New Civilian Personnel Cost	743,463	780,636	819,667	860,651
New Government Cost	1,747,119	1,485,689	1,559,975	1,637,973
Totals (4 yrs)	Contractor Cost		17,549,912	
	Old Government Cost		5,926,316	
	New Government Cost		6,430,756	

11. Corpus Christi Army Depot S 717 Motor Vehicle Maintenance

	1st year	2d year	3d year	4th year
Contractor Cost	176,255	157,873	157,873	157,873
Government Cost	133,729	133,729	133,729	133,729
Civilian Personnel Cost	83,136	83,136	83,136	83,136
New Civilian Personnel Cost	98,668	98,668	98,668	98,668
New Government Cost	149,261	149,261	149,261	149,261
Totals (4 yrs)	Contractor Cost		649,874	
	Old Government Cost		534,916	
	New Government Cost		597,046	

12. Corpus Christi Army Depot T 801 Packing and Crating

	1st year	2d year	3d year	4th year
Contractor Cost	816,935	760,935	760,935	760,935
Government Cost	434,405	439,186	440,402	439,836
Civilian Personnel Cost	185,406	185,406	185,406	185,406
New Civilian Personnel Cost	220,046	220,046	220,046	220,046
New Government Cost	469,045	473,826	475,042	474,476
Totals (4 yrs)	Contractor Cost		3,099,740	
	Old Government Cost		1,753,829	
	New Government Cost		1,892,389	

13. Edgewood Arsenal W 826 Programming Services

	1st year	2d year	3d year	4th year
Contractor Cost	254,117	210,259	210,259	210,259
Government Cost	124,828	124,828	124,828	124,828
Civilian Personnel Cost	117,690	117,690	117,690	117,690
New Civilian Personnel Cost	139,678	139,678	139,678	139,678
New Government Cost	146,816	146,816	146,816	146,816
Totals (4 yrs)	Contractor Cost		884,894	
	Old Government Cost		499,312	
	New Government Cost		587,265	

14. Edgewood Arsenal W 827 Data Processing

	1st year	2d year	3d year
Contractor Cost	116,612	113,079	113,079
Government Cost	80,795	74,645	74,645
Civilian Personnel Cost	58,159	58,159	58,159
New Civilian Personnel Cost	69,025	69,025	69,025
New Government Cost	91,661	85,511	85,511
Totals (3 yrs)	Contracter Cost		342,770
	Old Government Cost		230,035
	New Government Cost		262,682

15. Letterkenny Army Depot S 716 Motor Vehicle Operation

	1st year	2d year	3d year	4th year
Contractor Cost	828,329	813,947	854,644	897,377
Government Cost	648,554	680,981	715,030	750,782
Civilian Personnel Cost	458,667	481,600	505,680	530,964
New Civilian Personnel Cost	544,360	571,578	600,157	630,165
New Government Cost	734,247	770,959	809,507	849,983
Totals (4 yrs)	Contractor Cost		3,394,297	
	Old Government Cost		2,795,347	
	New Government Cost		3,164,696	

16. Letterkenny Army Depot T 801 Packing and Crating

	1st year	2d year	3d year	4th year
Contractor Cost	5,694,043	4,944,945	4,944,945	4,944,945
Government Cost	4,914,140	4,914,140	4,914,140	4,914,140
Civilian Personnel Cost	3,913,221	3,913,221	3,913,221	3,913,221
New Civilian Personnel Cost	4,644,333	4,644,333	4,644,333	4,644,333
New Government Cost	5,645,252	5,645,252	5,645,252	5,645,252
Totals (4 yrs)	Contractor Cost		20,528,878	
	Old Government Cost		19,656,560	
	New Government Cost		22,581,010	

17. Letterkenny Army Depot T 817 Other Non-Mfg. Opns.

	1st year	2d year	3d year	4th year
Contractor Cost	6,310,149	6,310,149	6,310,149	6,310,149
Government Cost	5,483,942	5,483,942	5,483,942	5,483,942
Civilian Personnel Cost	4,549,864	4,549,864	4,549,864	4,549,864
New Civilian Personnel Cost	5,399,921	5,399,921	5,399,921	5,399,912
New Government Cost	6,333,999	6,333,999	6,333,999	6,333,999
Totals (4 yrs)	Contractor Cost		25,240,596	
	Old Government Cost		21,935,768	
	New Government Cost		25,335,997	

18. Picatinny Arsenal   T 812 Rail Transport Services

	1st year	2d year	3d year	4th year
Contractor Cost	56,430	56,430	56,430	56,430
Government Cost	47,327	47,327	47,327	47,327
Civilian Personnel Cost	45,253	45,253	45,253	45,253
New Civilian Personnel Cost	53,708	53,708	53,708	53,708
New Government Cost	55,781	55,781	55,781	55,781

Totals (4 yrs)	Contractor Cost	225,720
	Old Government Cost	189,308
	New Government Cost	223,127

19. Picatinny Arsenal   X 931 Ordnance Equipment

	1st year	2d year	3d year	4th year
Contractor Cost	3,276,827	2,523,111	2,523,111	2,523,111
Government Cost	2,433,393	2,433,393	2,433,393	2,433,393
Civilian Personnel Cost	2,316,605	2,316,605	2,316,605	2,316,605
New Civilian Personnel Cost	2,749,420	2,749,420	2,749,420	2,749,420
New Government Cost	2,866,207	2,866,207	2,866,207	2,866,207

Totals (4 yrs)	Contractor Cost	10,846,160
	Old Government Cost	9,733,572
	New Government Cost	11,464,830

20. Picatinny Arsenal   T 801 Packing and Crating

	1st year	2d year	3d year	4th year
Contractor Cost	238,269	168,051	168,051	168,051
Government Cost	155,139	155,139	155,139	155,139
Civilian Personnel Cost	148,797	148,797	148,797	148,797
New Civilian Personnel Cost	176,597	176,597	176,597	176,597
New Government Cost	182,939	182,939	182,939	182,939

Totals (4 yrs)	Contractor Cost	742,422
	Old Government Cost	620,556
	New Government Cost	731,756

21. Tobyhanna Army Depot — T 801 Packing and Crating

	1st year	2d year	3d year	4th year
Contractor Cost	1,858,560	1,583,909	1,663,104	1,746,258
Government Cost	1,483,651	1,557,834	1,635,727	1,717,512
Civilian Personnel Cost	1,272,131	1,335,738	1,402,525	1,472,651
New Civilian Personnel Cost	1,509,805	1,585,296	1,664,561	1,747,788
New Government Cost	1,721,325	1,807,392	1,897,763	1,992,649
Totals (4 yrs)	Contractor Cost		6,851,831	
	Old Government Cost		[illegible],394,724	
	New Government Cost		7,419,129	

22. Tooele Army Depot — X 933 Screening and Crhshing Unit Operation

	1st year	2d year	3d year	4th year
Contractor Cost	67,095	67,095	67,095	67,095
Government Cost	28,441	28,441	28,441	28,441
Civilian Personnel Cost	15,431	15,431	15,431	15,431
New Civilian Personnel Cost	18,314	18,314	18,314	18,314
New Government Cost	31,324	31,324	31,324	31,324
Totals (4 yrs)	Contractor Cost		268,380	
	Old Government Cost		113,764	
	New Government Cost		125,296	

23. Watervliet Arsenal — T 801 Packing and Crating

	1st year	2d year	3d year	4th year
Contractor Cost	67,925	71,321	74,887	78,631
Government Cost	55,285	58,048	60,952	63,999
Civilian Personnel Cost	37,988	39,887	41,882	43,976
New Civilian Personnel Cost	45,085	47,339	49,707	52,192
New Government Cost	62,382	65,500	68,777	72,215
Totals (4 yrs)	Contractor Cost		292,764	
	Old Government Cost		238,284	
	New Government Cost		268,874	

24. Watervliet Arsenal S 716 Motor Vehicle Operations

	1st year	2d year	3d year	4th year
Contractor Cost	639,623	652,880	685,524	
Government Cost	239,152	205,726	215,281	
Civilian Personnel Cost	135,807	147,597	149,727	
New Civilian Personnel Cost	161,180	175,173	177,701	
New Government Cost	264,525	233,302	243,191	
Totals (3 yrs)	Contractor Cost		1,978,028	
	Old Government Cost		660,159	
	New Government Cost		841,018	

25. Watervliet Arsenal T 812 Rail Transport Services

	1st year	2d year	3d year	4th year
Contractor Cost	140,521	110,250	115,763	
Government Cost	69,795	73,284	76,947	
Civilian Personnel Cost	66,347	69,664	73,147	
New Civilian Personnel Cost	78,742	82,679	86,813	
New Government Cost	82,191	86,299	90,613	
Totals (3 yrs)	Contractor Cost		366,534	
	Old Government Cost		220,026	
	New Government Cost		259,103	

26. Fort Monmouth S 714 Furniture Repair

	1st year	2d year	3d year	4th year
Contractor Cost	104,055	111,703	111,703	111,703
Government Cost	88,682	101,312	101,312	101,312
Civilian Personnel Cost	73,937	85,755	85,755	85,755
New Civilian Personnel Cost	87,751	101,777	101,777	101,777
New Government Cost	102,496	117,334	117,334	117,334
Totals (4 yrs)	Contractor Cost		439,164	
	Old Government Cost		392,618	
	New Government Cost		454,497	

27. Savanna Army Depot T 812 Railroad Operations

	1st year	2d year	3d year	4th year
Contractor Cost	191,831	179,661	179,661	179,661
Government Cost	436,381	112,381	112,381	112,381
Civilian Personnel Cost	74,733	74,733	74,733	74,733
New Civilian Personnel Cost	88,695	88,695	88,695	88,695
New Government Cost	450,343	126,343	126,343	126,343

Totals (4 yrs)	Contractor Cost	730,814
	Old Government Cost	773,524
	New Government Cost	829,372

28. Savanna Army Depot S 712 Refuse Collection

	1st year	2d year	3d year	4th year
Contractor Cost	73,707	60,000	60,000	60,000
Government Cost	79,200	36,637	36,637	36,637
Civilian Personnel Cost	31,375	31,375	31,375	31,375
New Civilian Personnel Cost	37,236	37,236	37,236	37,236
New Government Cost	85,062	42,499	42,499	42,499

Totals (4 yrs)	Contractor Cost	253,707
	Old Government	189,111
	New Government	212,559

COST ANALYSIS WORKSHEET

For use of this form, see AR 235-5; the proponent agency is Office of the Deputy Chief of Staff for Logistics.

NAME OF INSTALLATION/ACTIVITY	FUNCTION			
Fort Rito	CITF 8713, Food Services			
COST ELEMENTS	**FIRST YEAR OF OPERATION**	**SECOND YEAR OF OPERATION**	**THIRD YEAR OF OPERATION**	**FOURTH AND FOLLOWING YEARS OF OPERATION**
CONTRACT OPERATIONS				
1. CONTRACT COST *(Price paid to supplier)*	483,338	483,338	483,338	483,338
2. TRANSPORTATION	2,000	2,000	2,000	2,000
3. CONTRACT ADMINISTRATION AND RELATED COSTS	12,509	12,509	12,509	12,509
4. GOVERNMENT FURNISHED MATERIALS AND SUPPLIES	1,211,096	1,211,096	1,211,096	1,211,096
5. CONTRACTOR USE OF GOVERNMENT OWNED EQUIPMENT AND FACILITIES	23,147	22,461	21,775	21,089
6. REHABILITATION, MODIFICATION OR EXPANSION OF GOVERNMENT OWNED EQUIPMENT AND FACILITIES	500			
7. INCENTIVE OR PREMIUM COSTS	9,667	9,667	9,667	9,667
8. STANDBY MAINTENANCE COST	400	100	100	100
9. OTHER COSTS	47,446			
9A. TOTAL	1,790,103	1,741,171	1,740,485	1,739,799
GOVERNMENT OPERATIONS				
10. MILITARY PERSONNEL SERVICES	145,161	145,161	145,161	145,161
11. CIVILIAN PERSONNEL SERVICES	448,421	448,421	448,421	448,421
12. OTHER PERSONNEL COSTS	9,634	9,634	9,634	9,634
13. MATERIALS, SUPPLIES, UTILITIES AND OTHER SERVICES	1,185,867	1,185,867	1,185,867	1,185,867
14. MAINTENANCE AND REPAIR	5,000	5,000	5,000	5,000
15. OVERHEAD COSTS	9,835	9,835	9,835	9,835
15A. SUBTOTAL *(Sum of elements 10 through 15)*	1,803,918	1,803,918	1,803,918	1,803,918
16. FEDERAL TAXES	9,022	9,022	9,022	9,022
17. DEPRECIATION	12,500	10,000	10,000	10,000
18. INTEREST	8,232	7,546	6,860	6,174
19. INSURANCE	5,412	5,412	5,412	5,412
20. OTHER INDIRECT COSTS	36,078	36,078	36,078	36,078
20A. TOTAL	1,875,162	1,871,976	1,871,290	1,870,604
GOVERNMENT OPERATIONS - OTHER (ISS/DIS/IAS)				
21. REIMBURSABLE COSTS				
22. ADMINISTRATION COSTS				
23. TRANSPORTATION				
24. MATERIALS, SUPPLIES, UTILITIES AND OTHER SERVICES				
25. PERSONNEL COSTS				
26. OTHER COSTS				
26A. TOTAL				

DA FORM 3207-R, 1 Nov 72 EDITION OF 1 NOV 69 IS OBSOLETE.

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OTHER PAPERS

The following papers are considered good research efforts but for one reasons or another, could not fit into the symposium

A FUNCTIONAL APPROACH TO DEFINING THE LOGISTICS ENTITY FROM A SYSTEMS PERSPECTIVE

Captain Roger P. Lempke
US Air Force

Captain Eric E. Nelson
US Air Force

Major Greg A. Mann
US Air Force

Captain William E. Smith
US Air Force

Captain Rodney M ineaux, Jr
US Air Force

Captain Michael A. Yanke
US Air Force

CHAPTER I

OVERVIEW

Our objective is to develop a model of the logistic process to be used in understanding the flow and interdependencies therein. Logistics is a process which has the objective of supporting an operation (7: 3-4). We reviewed many definitions of logistics and its related functions and processes in an attempt to place the development of a logistic process model in perspective. However, definitions found did not provide us the range and level of abstraction necessary to construct a truly representative model. Therefore, the following definitions were formulated based on our own education and experience:

1. Logistics--a process by which requirements determination, acquisition, allocation, and disposition of resources (material, manpower and money) can be effected in support of a job.

2. Job--a definable indenture of a mission in which resources are employed or consumed.

3. Mission--the reason for organizational existence.

Having defined the starting point for describing the logistic process, a framework was needed to display process interdependencies. We found that a general framework could be obtained in systems theory and a specific explanatory perspective and level of detail could be addressed using Black Box Theory. As typically defined, a system is a set of components surrounded by a boundary which accepts inputs from some other system and discharges outputs into another system (1:111). Systems theory is concerned with problems of relationships, structure, and interdependence rather than the constant attributes of objects (5:18). Open systems theory implies that the parts of a system do not completely determine the system's outcomes by themselves, but rather interact with an outside environment that represents situational uncertainty (6:99). The parts of the system are subject to influence by environmental stimuli not directly contained within the system.

Typically, a system's performance is more sensitive to changes in certain components than others. The detection and manipulation of these sensitivities in establishing priorities for changes to be made in the flow through the system is referred to as sensitivity analysis. System performance depends on the balance which is achieved among system components, measured in terms of capacity, timing, economics, and other measures. Often, performance reflects the effectiveness of the weakest or least efficient element in the system, regardless of the degree of technical sophistication or capability associated with other elements in the system. Optimum system performance does not necessarily depend on: (1) the optimum performance of each individual system component, (2) the ability to cut the single most important cost item in the system budget, or (3) use of the most advanced technology for system components. The management of systems involves cost tradeoff, which is a concept that relies on the belief that all activities and results can be translated into costs whether they are as a result of activities, e.g. contracting and training, or foregone opportunities, e.g. failure to perform a job and then aborting a mission (4:22).

A systems model may be developed by integrating the functions/processes of various subsystems. The outputs from one subsystem are simply the inputs to another subsystem via a myriad of complex paths or iterations. Adequately describing such a complex system depends on the use to which the description is to be put because in building systems from subsystems and in decomposing systems into subsystems the task may be conceptually infinite. In this respect it becomes obvious that, at some point, the effort required to describe the next subsystem level in detail is not worth the advantage gained in doing so. At this point the subsystem may be described in simple input-output terms and may be treated as a "black box," i.e. an entity which does known things in unknown ways with unknown mechanisms. Among the reasons why one may desire to apply the black box approach are: (1) the level of information needed concerning the system may be only superficial, or (2) understanding of the system in question may be so poor that to describe it in more specific terms would be counterproductive (2:46-47).

Our approach to constructing a model of the logistic process was also influenced by several considerations and characteristics which we felt were desired in such a model:

1. The model should be constructed to minimize bias to any one interpretation of the logistic process.

2. The level of model abstraction should be constructed so that the model would address any indenture of the logistic process or a series of sequential indentures in the logistics process in an iterative manner.

3. The model should be constructed to be relevant to the logistic process as it applies both to the commercial and military sections of the economy although, necessarily, some of the subprocesses are couched in military terms.

4. Unnecessary duplicative subsystems should be minimized so that the operation of the model in addressing a specific mission could be understood with relative ease.

5. In keeping with black box theory the detail of each subroutine should be detailed just enough to allow general model application without the combinational problems envisioned in addressing every possible contingency.

6. The model should be designed so that at any point, the model is able to generate additional iterations at the appropriate level of abstraction in support of the job currently in process.

The definitions, framework, characteristics, and considerations outlined in this introductory section are the basis for the detailed explanation of the model's mechanisms to be explained later.

CHAPTER II

REQUIREMENTS DETERMINATION

The requirements determination phase of the logistics network is engaged under the assumption that the mission input from the environment is in consonance with the system's objective. The transition from the "operations" aspect of the mission to the "logistical system" is ill-defined and unstructured. Thus, the point where the requirements determination phase begins is also, by its nature as a boundary phase to the logistics system, ill-defined. Continuous information exchange is required between the system's objective and the requirements determination phase so as to preclude the omission of required elements of logistics support or on the other hand possible definition of unnecessary logistics requirements. In either situation the need for timely information flow is essential to avoid costly corrections or adjustments later in the networks execution. It would be difficult to overemphasize the need for accurate communications as the consequences of a communication shortfall would compound the objective accomplishment in several respects: time, performance, and cost.

At the outset of requirements determination it is necessary to quantify the parameters or units of measurement of the resource. For example, "sorties" could be a gross unit of measure of a wings operation. With each "sortie" the units of resources could be further defined by manhours of crewchiefs, technicians, etc., and also by material and parts requirements in support of one sortie. Once discrete units of resources are established,an evaluation of risk and uncertainty of the objectives can be initiated and a determination made as to the feasibility of committing the necessary resource to the assigned task.

In risk analysis the system may be confronted with a situation no more complex than the routine movement of a standard non-critical item from Point A to Point B. Or possibly, the system may be tasked to support a space lab operation wherein the complexity of support, technological considerations and time factors take on a totally different perspective. Such that, in some instances the mission may be so important as to warrant essentially unlimited commitment of resources or as the former example may be evaluated 'non-essential' as the risk and uncertainty override the necessity of the logistical support due to excessive resource requirements. In essence, the risk and uncertainty analysis evolves around "cost" feasibility and where management decides tc continue or discoutinue resource commitment to the system's objective. If logistics support is determined infeasible the objective must be reevaluated in terms of its essentiality and either given greater priority or adjusted if logistical support is to be viable.

SUBROUTINE D

REQUIREMENTS DETERMINATION

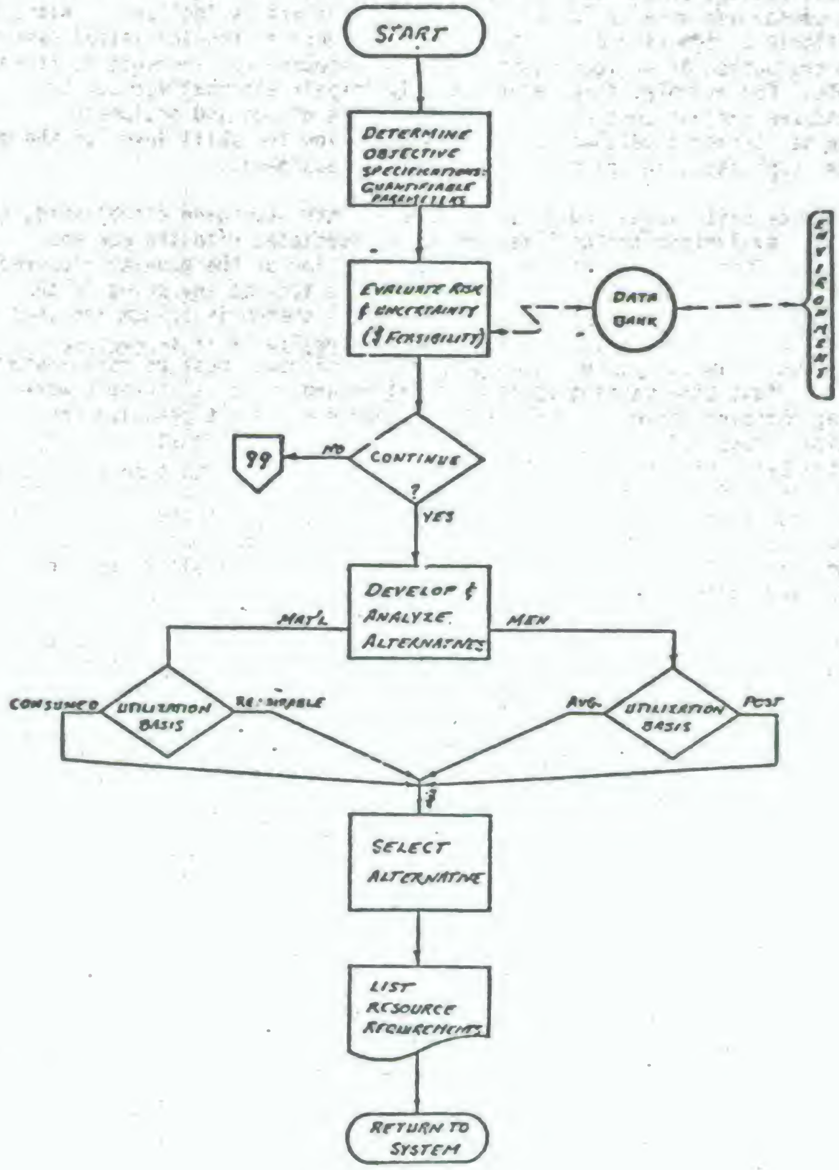

Figure 1. Requirements Determination

Assuming the risk and uncertainty involved in supporting the objective to be acceptable, the task then becomes one of developing and analyzing alternatives. Alternatives are developed within the scope of accomplishing the objective and involve the various combinations of men, material and dollars committed to the logistical task. Time indirectly could also be taken into account as a resource, particularly as it relates to scheduling and the decision of commitment of other resources. The common denominator in determining alternatives is "dollars." Although it is often difficult to identify dollar tradeoffs elsewhere in the logistical system, the alternative evaluation of various combinations of resource requirements is reasonably approachable. For example, in a radar assembly, repair alternatives can be formulated around the various cost or dollar combinations of men and equipment. Alternatives can be further developed to a detail involving the skill level of the men and the technical sophistication of the test and repair equipment.

Once the manpower skill level and material requirements have been established, the task becomes one of evaluating the utilization basis associated with the men and material resources. This decision is based on an evaluation of the penalty incurred by the total system in the absence of the resource or the item at any point in the system. In as much as a circuit breaker in an electrical system is seldom required to function it cannot be omitted because of the potential penalty if it is excluded as a system requirement. Similarly, the basis of required manpower must be established on the necessity of full-time manning (post-manning) regardless of a sporadic work load or on average manning where a potential system queue would not penalize the system's operation excessively. With materials, the orientation adjusts slightly with regard to the basis of material utilization. Considerations must be given to the cost of repairing an item (if possible) or declaring the item consumed in the operation. With fuel, for example, the determination is obvious in that the material is consumed. However, a generator, once failed could be repaired or considered consumed and the determination would most likely depend on the item's criticality, repair capability, MTTR, and costs.

As requirements are categorized on the basis of utilization they again can be quantified in terms of cost or "dollars." The specific resource requirements, once delineated, are assumed to be the most logical and rational list of requirements necessary to fulfill the desired alternative. However, once this alternative interacts with the mainstream of the logistical network and associated environmental factors, the potential for political override of the alternative and associated requirements is readily apparent.

CHAPTER III

ACQUISITION, ALLOCATION, AND DISPOSITION

The purpose of this chapter is to guide the reader through our logistical network. Some areas within the network are easily comprehended by just examining the flow chart. Other areas require a written explanation of the interfaces presented. This chapter is structured to explain the network from beginning to end but to only elaborate on those areas requiring extra explanation.

Deciding What is Needed (Figure 2)

Logistics provides a service; it does not fight a war, for example, it feeds resources to a war. A logistics network must receive a need for a service from an external source in order to have a reason to function.

Our OBJECTIVE DEFINITION block represents an input to the logistics network. A mission is defined, a job order is constructed, a telephone call is made--all these represent the communication of a need to our logistics network. That need becomes a job to the logistical network.

The indenture level of a job depends upon what level within an organization the job is spawned. A job at one level may become an objective for the next lower level. For example, a Wing Commander's job may be to have his Wing prepared for certain contingencies. That job translates into objectives for squadrons within the wing from which jobs are defined and performed.

It is important to conceive our logistical network as a horizontally flowing entity. A vertical hierarchy implies levels of importance. Our network presents a logical pattern to providing a service. No one step is more important than another. Each level of a bureaucratic hierarchy has its logistical network so a number of our logistic networks could be placed on top of one another to represent logistics at many levels within an organization's hierarchy. As in the example above, one level's job may become a lower level's objective.

Just as the environment excites the logistical network by presenting a need, it also determines to what extent logistics fulfills that need. As the decision block CONTINUE shows, the environment tells our logistical network when to stop working on a particular job.

Except for where a need enters our network and two other external interfaces, our logistical network is essentially a closed loop. Node 2 represents the point to which the network eventually loops to. Should the network not be able to handle a feedback situation then the situation may transfer from the logistics network to the environment via Node 99.

Evaluating Resource Requirements (Figure 2)

Chapter II discussed the transformation of objectives into physical resources. Once the resource requirements for a job are determined these requirements must compete for those resources within a limited resource arena.

The DETERMINE REQUIREMENTS PRIORITY subprogram is actually a queue. Requirements for resources to accomplish jobs enter a queue and are eventually satisfied. However, a priority algorithm rather than FIFO of LIFO procedures determines the order in which requirements are to be processed. For perhaps 80 percent (Pareto's Law) of the requirements the priority algorithm can assign a nonconflicting priority. However, the other 20 percent involve conflicts that are beyond the priority algorithm's scope. Therefore, in this subprogram management must sort out requirements with apparently equal priorities and, indeed, prioritize them.

LSP TEAM A

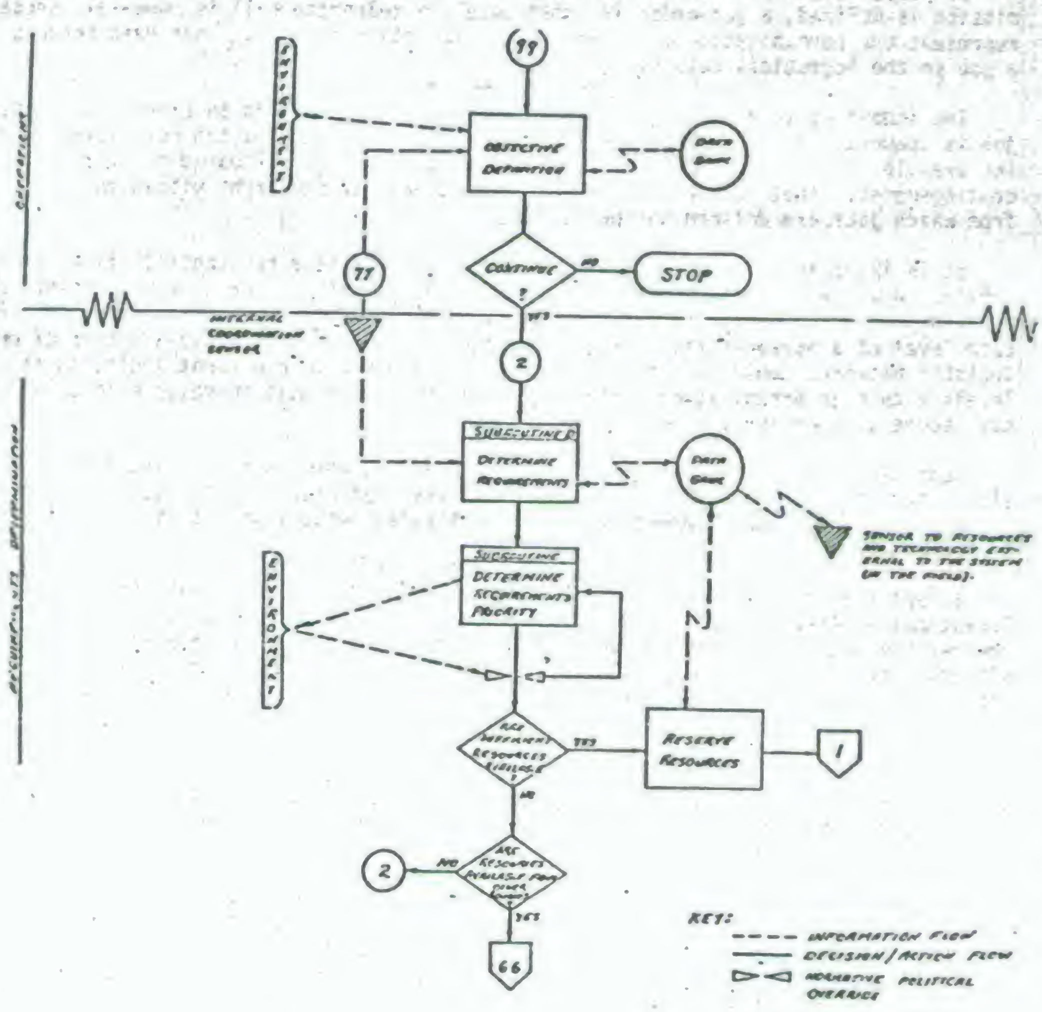

Figure 2. General Model

In our network the requirements priority becomes job priority. When a requirements package emerges from the queue it is immediately processed and as soon as the necessary resources become available they are focused on the job to be accomplished. A number of short circuit options exist within the network to temporarily abort jobs that obviously are not able to be accomplished within a reasonable time. However, the thrust of the network is to complete a job once the requirements for that job are released from the queue.

The purpose of the data bank and sensor connection to the DETERMINE REQUIREMENTS PRIORITY subprogram is to show that priority decisions are not made in a vacuum. Priorities are based on the most current guidance available and a feeling for attitudes within the outside environment. Even so, system interruptions may occur when certain parties within the environment are not satisfied with the priority assigned a job.

Our network accounts for a political override of the priority decision shortly after it is made. Actually, a political override may occur at any point in our logistics network. However political overrides occur primarily to change priorities for two reasons. First, once a job moves into our system, abrupt changes in priority become difficult to accomplish because of the momentum of the system. Those outside the system understand this so they try to influence priority changes before momentum builds. Second, those outside a logistics system tend not to understand its internal workings so attempt to influence a job that they favor early, before the job gets too deep into the logistics system.

After priorities have been established and a job moves forward in our system to be processed, but before acquisition begins, we search our own system for resources already available. Any resources that are already available from other sources within the system that do not require formal acquisition are reserved. If some or all of the resources necessary to perform a job are not available within the system, the formal acquisition process is entered. The network describing this process is discussed later. Assume for now that resources are available so that we can move to the distribution phase.

Getting Resources to the Job (Figure 3)

The purpose of the REVALIDATE REQUIREMENTS block and the HAS THE OBJECTIVE CHANGED question is to check that a proposed job has not had a requirements alteration or a re-definition. Following this, job resources enter the distribution process which is discussed under its own heading.

The Job (Figure 3)

The job represents our logistics network's service to a customer. Logistics does not actually perform the mission but jobs are necessary so that the mission can be accomplished. For example, logistics does not fly a bombing mission but the services it provides make the launch of a bomber aircraft possible.

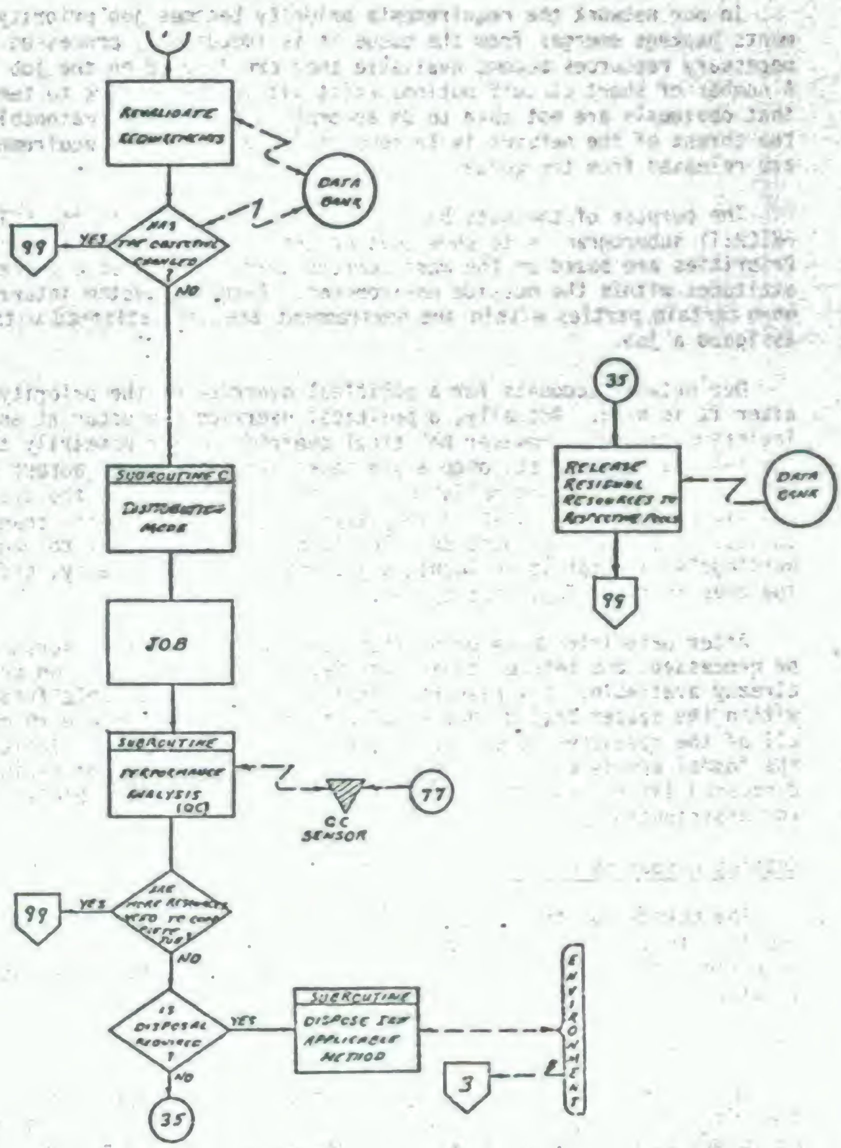

Figure 3. General Model
(Continued)

As discussed earlier, in a bureaucratic hierarchy our logistics network may be applied to any layer within that hierarchy. A job may entail "turning a screwdriver" to preparing a briefing for the Chief of Staff. In either case, our logistics network brings resources together and performs a job that in turn supports a mission.

Job performance quality influences the possiblity of success of a mission. Therefore, quality control is as important to those who must perform a mission as well as those involved in accomplishing a job in support of that mission. The purpose of our PERFORMANCE ANALYSIS subprogram is to sense, compare, and judge against standards the jobs performed in our logistics network. Node 77 connects contract administration and those interested parties outside the logistics network with our quality control program. Interfaces occur among these three activities to insure that a job is performed properly.

If a job cannot be completed with the resources available to it new requirements must be evaluated by our logistics network. Note that even though a job is not complete, its additional requirements must still compete for resources along with other resources.

When a job is completed its remaining resources must be disposed. Disposal is covered as a process in a separate section.

So far, our logistics network has been presented without addressing the process subprograms. These are now discussed individually below.

Acquisition Process (Figures 4 and 5)

Men, materials, and money--the 3Ms--are the main resources used by a logistics system to support a given objective or mission. Many times these resources are not available from within the system's own capability to provide and have to be acquired from alternative sources. These alternative sources can be described in the context of the type resource to be acquired, once the resource is identified. The acquisition process of our logistics network interrelates both external and internal functions. Its efforts are affected by key decisions regarding mission objectives, levels of support, priority classifications, and changes to all three. These areas are of primary concern to the logistician, especially in the acquisition process, as he must perform cost/time tradeoff analysis, among other considerations, to determine the most effective means of acquiring each needed resource.

Materials. When material is required, the first step is to determine the source from which it can be most effectively acquired in light of the assigned priority. This task is accomplished by considering tradeoffs among the possible actions in the following table:

Repair	Existing Material	Contract	DOD-owned asset Industry-owned asset
Modify	Existing Material	Contract	DOD-owned asset Industry-owned asset
Manufacture	Asset	Contract	for asset
Purchase	Asset	Asset	

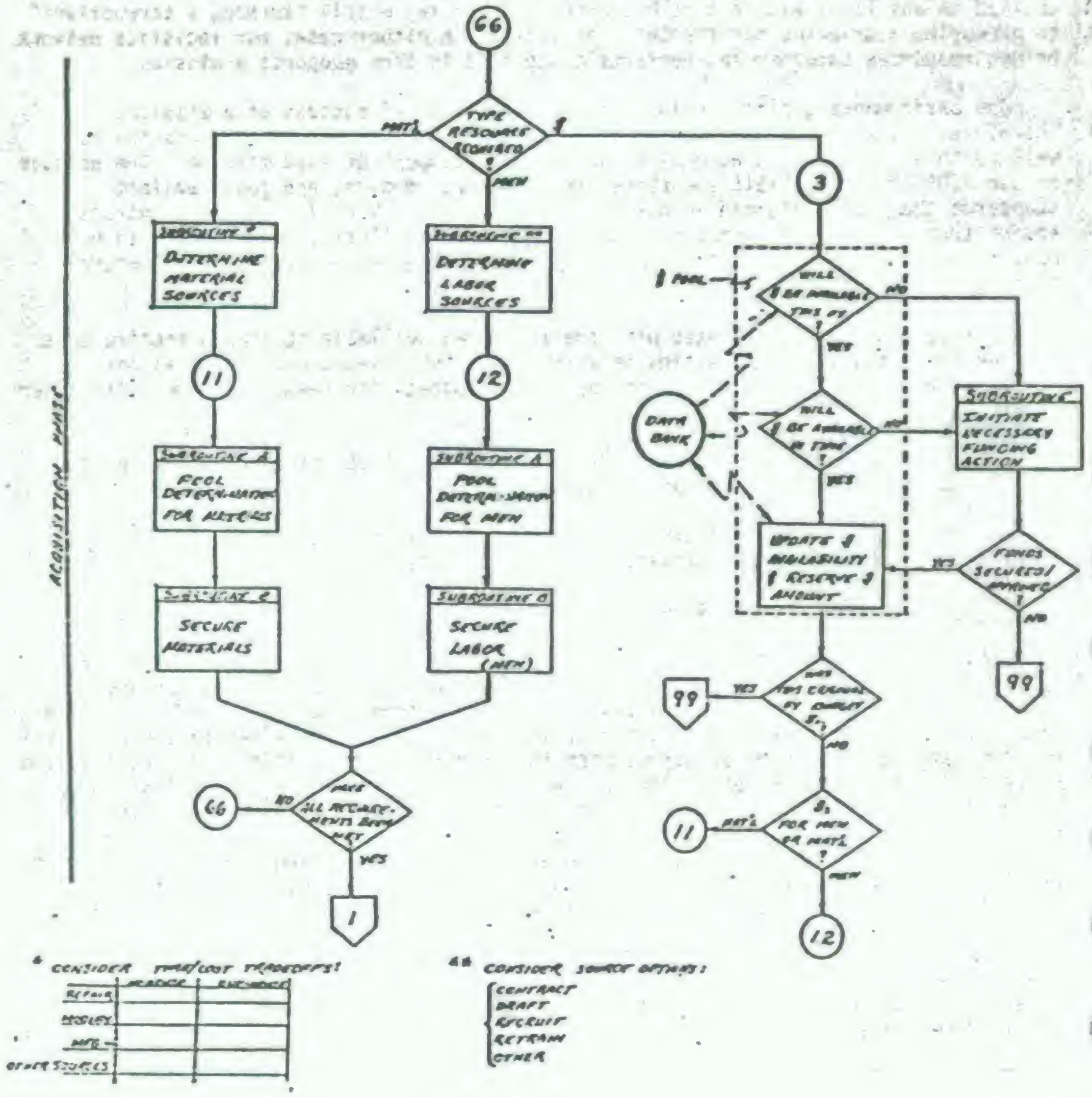

Figure 4. Acquisition Process

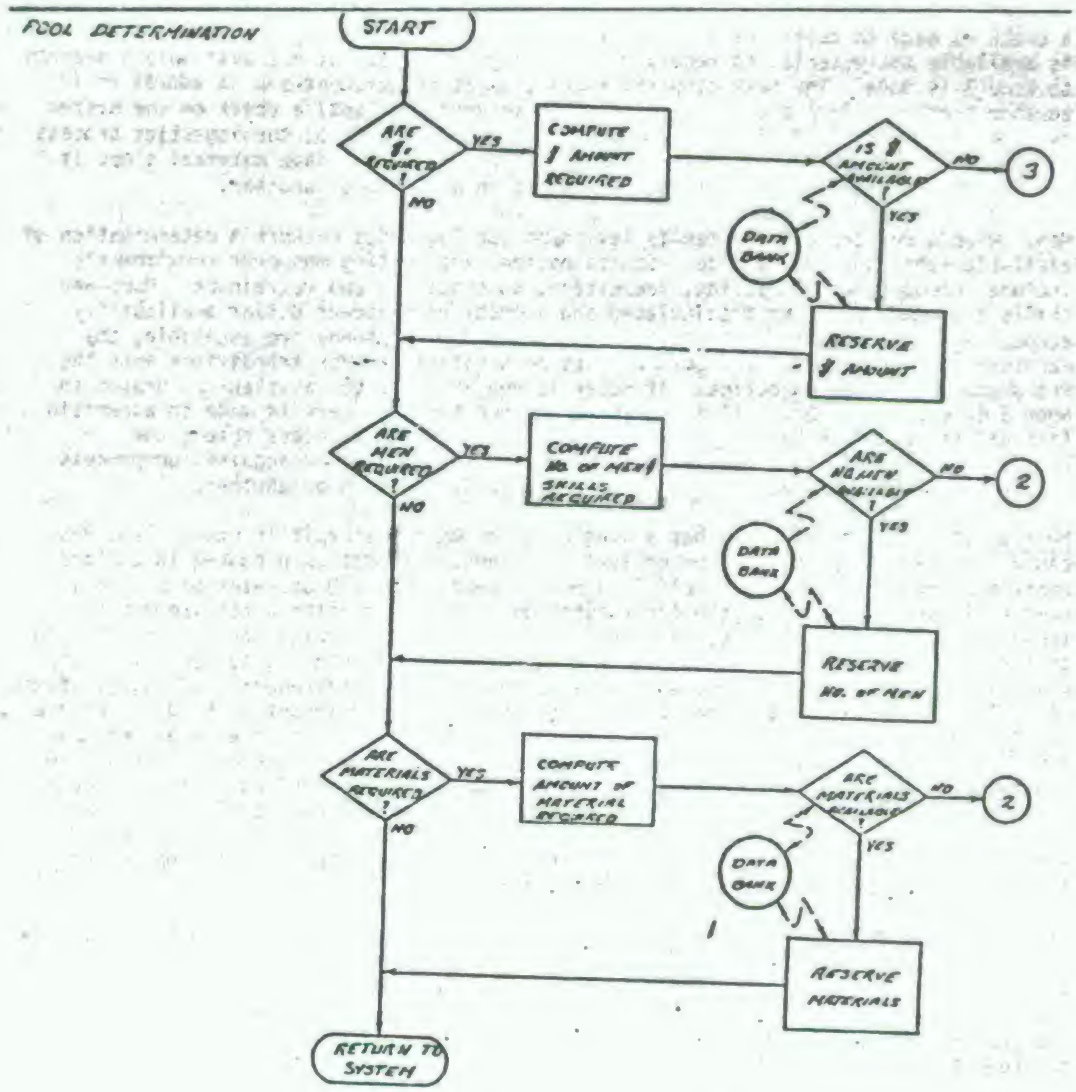

Figure 5. Pool Determination

Once the method of acquisition has been determined and the amount of material computed, a check is made to determine if money is available. If no money is needed or money is available the material is reserved. If money is needed but not available a branch to Node 3 is made. The next step (Subroutine B) is procurement and is addressed in another section. Once the material has been secured (in hand) a check on the system is made to determine if all requirements have been met. If so, the logistics process enters the Distribution Phase; if not, a recycle through the same material steps is performed until all requirements have been met in one form or another.

Men. When a requirement for men is levied on our logistics network a determination of available labor sources is made. Source options for meeting manpower requirements include, among others, drafting, recruiting, contracting, and retraining. Manpower skills and numbers are next calculated and a check on manpower dollar availability accomplished. If no money is required, or if sufficient funds are available, the manpower requirements are reserved and the acquisition process transitions into the Procurement Process subroutine. If money is required but not available, a branch to Node 3 is executed. Once all men are secured (on hand) a check is made to ascertain that all requirements have been met. If so, the logistics process enters the Distribution Phase; if not, a recycle through the same manpower acquisition process takes place until all requirements have been met in one form or another.

Money. If a logistics system has a single common denominator, it is money. The 3Ms can all be expressed in terms of dollars. The annual budget is prepared in dollars. Occasions arise where money itself is a requirement. The DOD operates on a fiscal year (FY) basis and as such, the first question to be asked after a requirement for money has been established is, will the money be available during the current FY? An affirmative answer to this question will result in still another interrogative statement: will it ($) be available in time to meet its requirement? If so, an update of the dollar availability data bank is made and the proper amount is held in reserve for the intended purpose. In case the FY allocation cannot cover the money requirement, separate steps are initiated to request the additional/supplemental funds once it is determined that additional/supplemental funds will be received in time to meet the requirement. Once the allocation is received, the dollar availability data bank is updated and the funds are reserved for their intended purpose. If funds are not approved or will not be received in time, then a breakout of the acquisition process is made, leading back to Node 99 for further decision-making.

Procurement Subroutine. The procurement subroutine relates specifically to a military environment as outlined in the Armed Service Procurement Regulation (ASPR) although the techniques and tradeoffs cited may be used in a commercial setting. The first step in the procurement subroutine is to conduct an acquisition analysis to establish a basis from which an appropriate contract type may be determined. There are several considerations in the analysis including the following:

(1) Price analysis of the industry

(2) A cost estimate of the goods or services of interest

(3) Determination of the urgency of the requirement

(4) The technical capability and financial responsibility of the contractors

(5) Adequacy of the various contractors' accounting system

(6) Other concurrent contracts held by the prospective contractors.

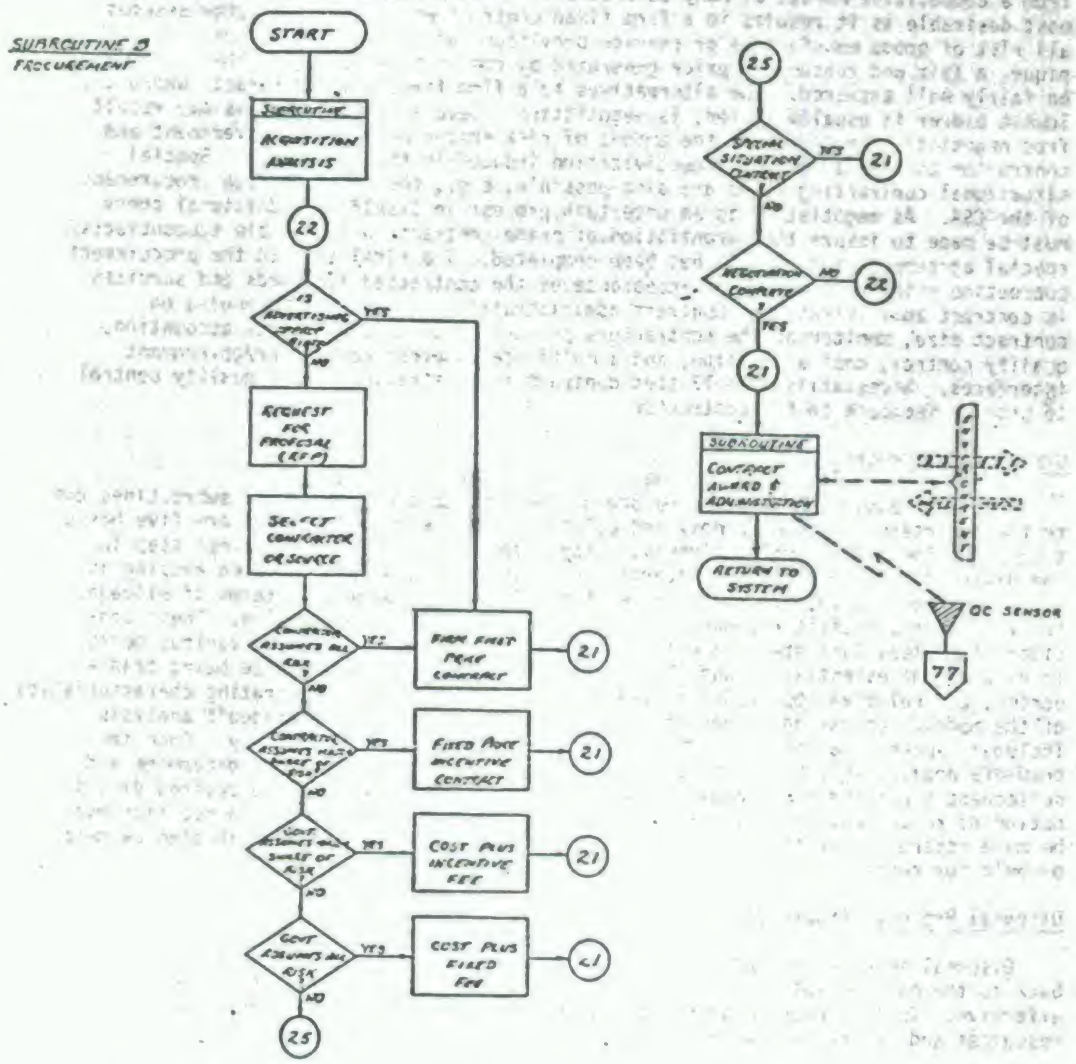

Figure 6. Procurement Subroutine

The next step is to determine if advertising is possible, i.e., soliciting a contract from a competitive market of many contractors. This procurement technique is the most desirable as it results in a firm fixed contract where the contractor assumes all risk of goods manufacture or service provision; and under this contracting technique, a fair and reasonable price generated by competitive forces in the market can be fairly well answered. The alternatives to a firm fixed price contract, where the lowest bidder is usually chosen, is negotiation. Several contract types may result from negotiation depending on the amount of risk shared between the government and contractor and the amount of incentivization induced in the contractor. Special situational contracting types are also possible, e.g., the total package procurement of the C5A. As negotiation is an uncertain process in itself, an additional check must be made to insure that negotiation of prime contracts and possible subcontracts/special agreements and clauses has been completed. The final step in the procurement subroutine prior to receipt and acceptance of the contracted for goods and services is contract administration. Contract administration can involve, depending on contract size, monitoring the contractors production process, supplies accounting, quality control, cost accounting, and a multitude of other contractor/government interfaces. Necessarily Node 77 ties contract administration to job quality control to provide feedback to the contractor.

Distribution Process (Figure 7)

The distribution process can be one of the most complex of all the subroutines due to the uncertainty of the economy and political considerations. There are five basic transportation modes: rail, highway, water, pipeline, and air. The first step in the distribution process is to determine what is needed, where, and when keeping in mind that the relative importance of each model can be measured in terms of mileage, traffic volume, traffic revenue, and the nature of traffic composition. These considerations lead into step two which is a tradeoff analysis among the various modes in view of the essentiality and characteristics of the good or service being transported, the relative importance of transportation mode, and the operating characteristics of the modes. Operating characteristics which should be used in tradeoff analysis include: speed, availability, dependability, capability, and frequency. Once the tradeoff analysis has been completed, an additional step is needed to determine and subsequently acquire additional resources necessary to accomplish the desired distribution of resources, e.g., a forklift or money for postage. Finally, a decision must be made regarding partial distribution, i.e., should the partial distribution be made or held for receipt of the entire requirement.

Disposal Process (Figure 8)

Disposal involves a planned interface with the environment to pass resources back to the environment after job completion. Sometimes rejuvination is cost effective. In this case rejuvination constitutes a new requirement that demand resources and, therefore, a priority.

If rejuvination is not desired, used resources are passed to the outside environment by sale, decomposition, mothballing, or junking. Any of these activities involve jobs that must be performed. In some cases, resources, usually in the form of money, are passed back to our network and routed to the money pool.

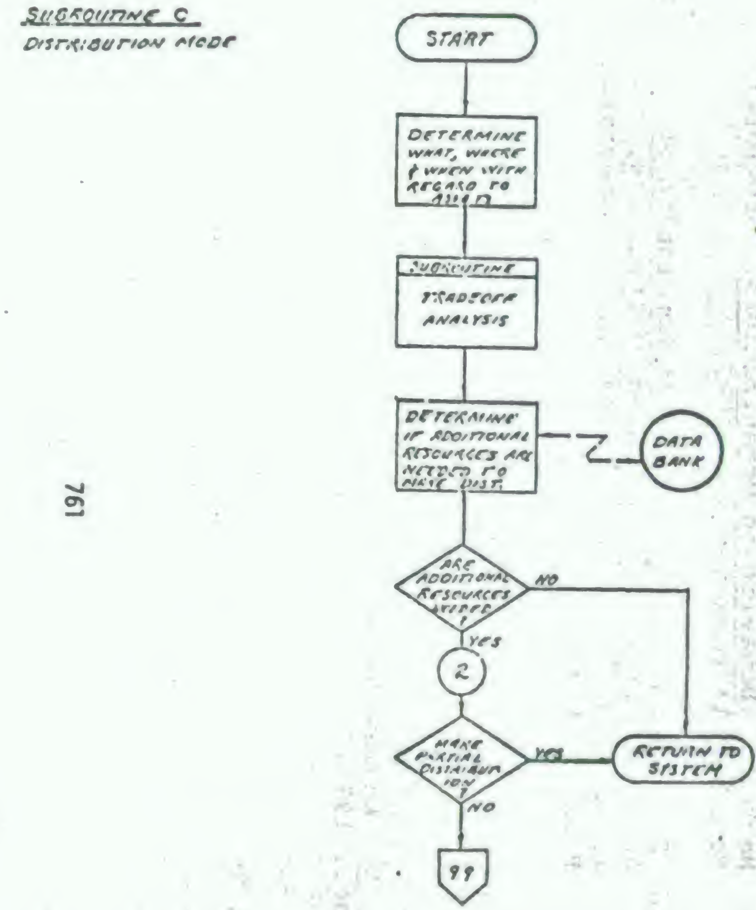

Figure 7. Distribution Process

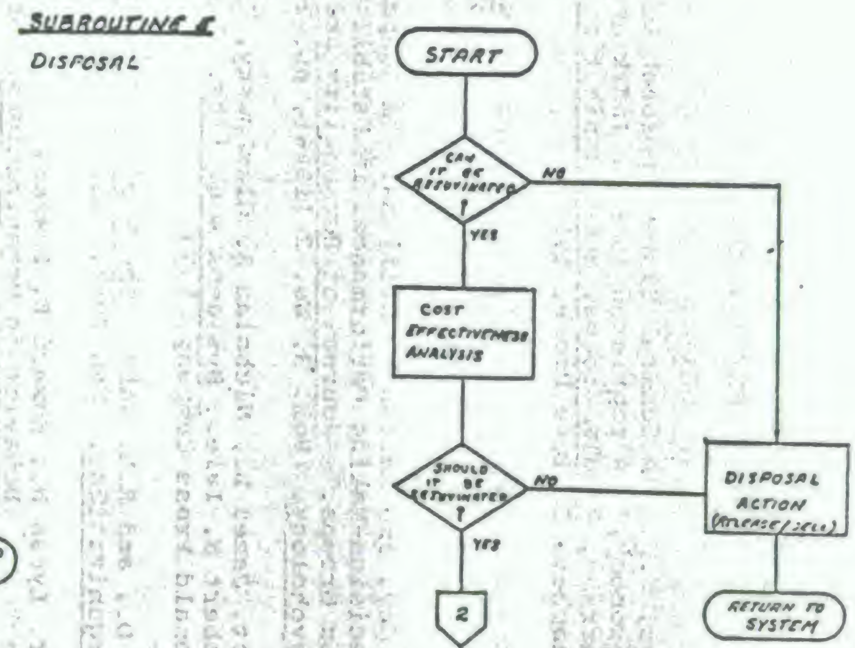

Figure 8. Disposal Process

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AN EMPIRICAL INVESTIGATION OF CHANGES IN DIRECT LABOR REQUIREMENTS RESULTING FROM CHANGES IN AIRFRAME PRODUCTION RATE

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There are many instances where the production rate of an aircraft airframe manufacturing program is changed due to reasons external to the production process. The stretchout of B-1 bomber production and F-15 fighter production for budgetary reasons in 1977 are examples of changes that slow down production. The change of F-4 production from 12 to 67 aircraft per month during the Vietnam emergency is an example of a case where production was accelerated.

These exogeneous changes in production rate are accompanied by a need to know their effects on cost. Annual budgets must be adjusted. Contracts must be renegotiated. It follows that there is a need for a procedure to systematically estimate the effect of changing the production rate on the cost of producing aircraft airframes.

A primary element in a cost estimate is the number of direct labor hours required to output the product. Many other cost elements in the indirect cost category are factored on direct labor. Therefore, an improvement in the ability to estimate total cost would logically start with an improvement in the ability to estimate direct labor hours. Accordingly, this effort is focused on estimating the change in direct labor hours resulting from a change in aircraft production rate.[1]

In the paragraphs that follow, other contributors to the literature are briefly surveyed and a shortcoming of learning curve techniques is explored. Then a theoretical discussion of the production rate is presented. An approach for adding a production rate variable to the learning curve model is postulated. A section describing an empirical test of the approach follows and the paper closes with a summary of findings and some conclusions. But first it is proper and important to look at some of the thoughts of other authors when considering the effects of production rate on direct labor resource requirements.

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[1]This paper is extracted from the doctoral dissertation of Lt Col Larry L. Smith (12). A copy may be obtained through the Defense Documentation Center under file number ADA026112.

Other Contributors

A number of people have investigated the effects of production rate on unit production costs. By no means have their findings been unanimous. Summaries of the more important works are presented in chronological sequence beginning with an older work by the French writer Guibert. Guibert considers the production rate to be an important cost determinant of unit labor cost because of its proportional relationship to the number of tools required (5:64). His models relate unit production cost to cumulative quantity at four different rates of production: 10, 20, 50, and 100 units per month. At any unit of production, the models predict higher unit costs at higher rates of production.

Joel Dean explores the relationship between cost and rate of output in his book on managerial economics. Based largely on previous evaluations of empirical data from a hosiery mill, a leather belt shop and a furniture factory that were generated in the 1930's, he concludes that the most important independent variable in determining short run cost is the rate of output (3:292). He further observes that unit costs are generally constant over the range of different production rates included in the samples (3:272-273).

Harold Asher writes on the relationship between cost and quantity in the airframe industry. In the course of examining empirical data for many different airframe production programs, he subjectively evaluates the effect of production rate on direct labor hours. His conclusion is that production rate is not a very important predictive variable. Asher says that production rate " . . . is felt to be of minor importance, within a certain range of rates of production, and definitely subordinate to the effect of cumulative production (2:85).

Asher does not attempt to separate the effect of production rate from the effect of cumulative production on unit cost. He notes however that there are at least two ways in which the rate of production can influence unit labor cost. First, it can affect the number of hours of machine set-up time charged to each unit. Second, it can affect the number of subassemblies employed in the manufacturing process. This in turn affects the number of hours for subassembly work charged to each unit. He concludes that except for these two effects, there is little reason to expect the unit hours for a 200 unit per month case to be significantly fewer than for a 30 unit per month case (2:87).

Alchian and Allen advance the idea that production cost is dependent on three production variables. The variables are the total volume of the item to be produced, the production rate and the time span from the decision to produce until the first item is output (1:308). These writers further suggest that unit costs should increase with increasing production

rates. This behavior is attributed to the fact that higher production rates require use of more overtime and reliance on less efficient workers (1:315).

Gordon Johnson describes an approach to estimating direct labor requirements when production rate changes occur on rocket motor production lines (6:25-41). He develops a model from empirical data that incorporates both the rate effect and the learning effect in estimating direct labor hours. Johnson's approach is to regress direct labor hours per month as a linear function of production rate in equivalent units per month and as a power function of cumulative units produced as of the end of each month. He reports mixed results on the four test data sets. The model is somewhat awkward to use because the analyst must estimate one of the parameters.

Joseph Orsini tests Johnson's rocket motor model on C-141A airframe production data to determine if the model is adaptable to the airframe production industry (11:53-80). In the C-141A program, there is no indication that the production rate is explicitly changed in midprogram although the data reflect that the production rate gradually varies throughout the program.

Orsini reports that the three variable model developed by Johnson fits the C-141A data better than a standard learning curve model. He concludes from this comparison that rate is a significant factor in determining manufacturing labor hours.

For further comparison, Orsini also tests the C-141A data in a linear form of the multiplicative model $y = e^A x_1^B x_2^C$ where:

y represents direct labor hours per month,

x_1 represents the production rate in equivalent units per quarter,

x_2 represents cumulative units produced as of the end of each month and

A, B and C model parameters.

This multiplicative model fits the data better than does the Johnson model. Orsini suggests that " . . . the multiplicative models may be more suitable for analysis than Johnson's model because they eliminate the requirement for estimating one parameter (11-71).

Fazio and Russell overview the entire airframe production cost estimating problem in terms of the sensitivity of each decision variable to the production rate (4:1). Their objective is to find the optimum rate of

production given the decision variables of production scheduling. The approach is analytical as contrasted to the statistical investigations of historical data reported by Johnson and Orsini. Fazio and Russell observe that the number of parallel production lines or stations is an important determinant of direct labor hours per unit. They conclude that the installation of " . . . duplicate load centers, which may be required for higher rates of production, will in fact reduce the overall rate of learning and thereby increase total manufacturing hours for a fixed buy (4:66). They further note that the efficiency of the labor force varies by shift. Accordingly, the direct labor hours required to produce each unit could also be expected to vary with the number of shifts employed (4:68).

Three investigators from the Rand Corporation, Large, Hoffmayer and Kontrovich, report on a search for parametric cost models that would enable program planners to project the magnitude of costs that could be expected at different production rates (8:1). They use statistical techniques to examine the effects of airframe production rate and other selected design parameters on major cost elements. The investigation is an aggregative approach where a few descriptors from each of many programs are evaluated simultaneously through multiple regression analysis. The purpose is to develop a general cost model suitable for predicting costs of other programs. Their evaluation shows that the chosen proxy for the production rate is of little value in explaining the variation in cumulative labor hours among the different programs. The investigators conclude that the influence of production rate cannot be predicted with confidence on the basis of the analysis performed (8:50-51).

Large, Hoffmayer and Kontrovich also evaluate the cost model proposed by Johnson for rocket motor direct cost estimating and later tested by Orsini with airframe production data. Using data from seven different airframe production programs, they found that "In none of the programs did the inclusion of production rate improve the coefficient of determination (R^2) by as much as one per cent over that obtained using cumulative quantity alone" (8:49).

Joseph Noah reports on a statistical analysis of cost data to discover the effect of production rate on airframe cost (9:1). His research includes the major cost elements for two fighter airframe production programs, the A-7 and the F-4. Noah analyzes all the major elements of airframe cost but his findings on direct labor hours are of particular interest here. For the two programs studied, he reports that the following relationship models the data well:

$y = e^A . x_1^B . x_2^C . x_3^D$ where:

y represents the average direct labor hours expended per pound of airframe produced for each airframe lot,

e is the base of the natural system of logarithms,

x_1 represents the cumulative volume expressed as pounds of airframe produced through the midpoint of each successive airframe lot,

x_2 represents the production rate expressed as the average pounds of airframe delivered per month for the period spanning the first and last delivery of the lot,

x_3 represents the annual volume of aircraft ordered, expressed in airframe pounds and

A, B, C and D are model parameters.

Noah generalizes the cost model by averaging the estimated regression coefficients derived from the two sets of cost data. He suggests that this generalized model can be used to predict the effects on cost of changing the production rate of the F-14 airframe production program. Noah concludes that "Our findings suggest that delivery rate as a proxy for production rate has a significant effect, and an important one, on the production cost of airframes" (9:41).

All of the literature reviewed reflects a common interest in the relationship between production rate and direct labor requirements. But the authors do not agree on the form or the importance of that relationship. Some write of increasing unit cost with increasing rate while others express the opposite viewpoint. Some write of no significant effect of rate on unit cost while others suggest that rate is an important independent variable. This research tests the idea that the production rate changes can explain changes in direct labor requirements. Furthermore, it is postulated that an increase in the rate will cause a decrease in the unit labor requirement within the relevant capacity of a given plant.

A Shortcoming of Learning Curve Techniques

Direct manufacturing labor hours in the airframe industry are often predicted using learning curve techniques. These techniques are quantitative adaptations of the idea that individuals performing repetitive tasks exhibit a rate of improvement due to increased manual dexterity. Observations of complex airframe assembly operations reveal that management innovations such as work simplification, environment improvement and engineering changes also contribute to the rate of improvement. It is subsequently found that this rate of improvement occurs in a regular pattern and can be predicted by using a simple model. One form of the model, the unit learning curve model, can be expressed as;

$y_i = B_o * X_{1i}^{B_1} * 10^{\varepsilon_i}$ where:

y_i represents the direct manufacturing labor hours required to output each pound of airframe in lot i.

x_{1i} represents the cumulative learning on all airframes of the same type through lot i.

B_o is a coefficient that represents the theoretical number of direct manufacturing labor hours required to make the first unit and

B_1 is a coefficient that reflects the rate of improvement that exists in a particular manufacturing environment.

ϵ_i represents the variation in the dependent variable that is not explained by the model for each observation i.

i denotes the observation number.

The model is more intuitively appealing when one observes that as the total quantity of units produced doubles, the cost per unit decreases by some constant percentage (10:50). The model is also frequently used in a form where the y value is expressed as the cumulative average hours per unit rather than in instant hours per unit.

It is important to note that while the learning curve is essentially a trend concept, it is not a time series trend form. Rather, the independent variable is taken to be the number of opportunities to learn while the dependent variable is cost input per unit of production (7:1). Accordingly, 500 airframes produced at the rate of 50 per month would be predicted by the model to require the same number of direct manufacturing labor hours as 500 airframes produced at the rate of ten per month when the same rate of learning (B_1 coefficient) is assumed.

This lack of sensitivity of the learning curve model to the production rate is a problem if the rate is explicitly changed in midprogram. Logically, direct labor requirements per airframe should change as a result of a forced change in the production rate. The worker who senses the pressure of an increased production rate should be motivated to work faster than the worker who senses a production line slowdown. Higher rates of production should permit greater worker specialization than lower rates where one worker would be expected to accomplish multiple tasks. Tool and tooling set-up costs can be spread over a greater number of units at higher production rates. These factors suggest that the production rate should be considered as a variable in the models used to predict the direct labor hours required to manufacture an airframe.

The Production Rate

An airframe production rate can be defined in different ways for different purposes. Two proxies for the production rate are used in this study. They are a lot average manufacturing rate and a delivery rate.

A lot average manufacturing rate is constructed by dividing the number of airframes in a lot by the time required to produce the lot. The lot release date for the first airframe in a lot and the airframe acceptance date for the last airframe in a lot define the extremes of the lot time span. This form of the production rate is easy to construct and appears to match well with lot average labor hour expenditures. However, the averaging process obscures any learning or rate effect within a lot. Thus when the lots are released infrequently, such as once a year, the number of observations is limited and the data are somewhat distorted.

A delivery rate can be developed by averaging monthly acceptances for each lot. If direct labor requirements are available for each airframe, the actual monthly airframe acceptance rate can also be used to develop cases for analysis. Historical acceptance data are readily available and delivery rates are easily forecasted from contract delivery schedules. Thus the delivery rate is also a possible candidate as a production rate proxy.

A Cumulative Production and Production Rate Cost Model

This study is based on the assumption that the production rate affects the quantity of direct labor hours required to manufacture an airframe. Since cumulative production has been shown to be a strong explainer of changes in the direct hours required to produce an airframe, addition of a production rate variable to the learning curve model should explain additional variation in the direct labor requirement. Accordingly, a three variable model is suggested as more suitable for explaining and predicting variation in direct labor requirements than is the cumulative learning model. The model suggested is

$y_i = B_0 \cdot x_{1i}^{B_1} \cdot x_{2i}^{B_2} \cdot 10^{\varepsilon_i}$ where:

y_i represents the unit average direct labor hours required to output each pound of airframe in lot i,

x_{1i} represents the cumulative learning achieved on all airframes of the same type through lot i,

x_{2i} represents the lot i production rate for all airframes of the same type,

ε_i represents the variation in the dependent variable that is not explained by the model for each observation i and

B_0, B_1 and B_2 are parameters in the model.

The production rate is chosen for inclusion in the model in the multiplicative form for a number of reasons. Other writers have suggested that it might be a good predictor in this application. Multiple regression analysis is facilitated by this choice. Finally, investigation of some test data indicates that it works well.

An increase in the production rate within the planned plant capacity should cause a decrease in the hours required to manufacture each airframe. A rate decrease should produce the opposite reaction. This theory is supported by the ideas of specializing labor, prorating set up time and motivating workers to produce.

The management concept of specializing labor to increase efficiency supports the idea that the rate and the direct production labor hours should be inversely related. At higher rates of production, more workers are added. This permits the foreman to assign each worker fewer tasks which are performed more frequently. Thus, in addition to the increased proficiency which accrues due to the learning process, some of the time that would be required to change from one task to another is saved. At decreased rates of production, the opposite cost behavior is expected as workers are removed from the production line and the remaining workers are required to perform additional tasks.

At higher rates of production, the hours required to set up machines for fabricating airframe parts can be spread over more airframes because of the accompanying larger batch sizes. This should also contribute to an inverse relationship between production rate and labor requirements.

Finally, it appears logical that the worker who senses the pressure of a high production rate will be motivated to work faster than the worker who is not pressed to finish a task because the level of effort is diminishing. This assumption is supported by the "toe-up" phenomenon familiar to students of the airframe production process. The "toe-up" phenomenon is an increase in the direct hours required to manufacture airframes that is frequently experienced as a production program is concluded and the production rate is decreased toward zero.

Least squares multiple regression analysis is used to examine historical airframe production data in the cumulative production and production rate cost model. To facilitate the regression analysis, the model is transformed by extracting the common logarithm of each term. The transformed model is $\log y_i = \log B_0 + B_1 \log x_{1i} + B_2 \log x_{2i} + \varepsilon_i$. The model is now linear in each term.

Three hypotheses are tested in the research effort. The first is that the production rate, when expressed in the cumulative production and production rate cost model, can explain an important part of the variation in the total direct labor requirements to build an airframe. The second is that the model can be employed to explain the variation in the hours required to fabricate and assemble the airframe. The third is that the model is suitable to predict the hours required to produce additional airframes for the cases examined in the first two hypotheses.

Analysis Approach

The cumulative production and production rate cost model is evaluated using historical data sets from three airframe production programs: F-4, KC-135 and F-102. The selection of programs examined is guided by convenience and accessibility of data. The F-4 data are the most complete and comprehensive of the three programs. These data are used to test all three hypotheses. The F-102 data appear to be very accurate but are limited to total hours. Accordingly, hypothesis two is not evaluated with F-102 data. The KC-135A data are available in both total hours and lower process level hours.

The research procedure is to examine a total of 16 data sets from the individual programs through application of multiple revision analysis. Coefficients are estimated from a data set that tailor the proposed cost model to that set. Then the predictive ability of that model is tested. There is no intent to develop a generalized cost model, only a generalized approach to building tailored cost models. In this sense, each data set from each program represents a unique population.

One way to test the predictive ability of the full model is to successively remove a few of the most recent cases from the data set. One may then perform the regression analysis with the remaining data to develop new regression coefficients. Using the model developed from the truncated data set, one can forecast the points that are removed. A comparison between the forecast and the observed values gives a measure of the predictive ability of the model tailored from the truncated data set. As successively larger increments of data points are removed from the original data set, a family of estimated regression coefficient sets is developed for the cost model. Each of these tailored models can be used to predict some particular future data point. These predictions, compared to an observed value, are the basis for subjective evaluation of the ability of the model to forecast.

Findings and Conclusions

The cumulative production and production rate cost model fits the individual data sets well. In each of the sixteen sets of data the model is found to be appropriate. Statistical tests to support this conclusion are conducted at the 0.05 level of significance. More specifically, one indicator of goodness of fit is the R^2 statistic for the full model. As reflected in Table 1, which summarizes some regression results for all 16 models, the R^2 full statistic is respectable in each case.

The production rate variable contributes importantly to the explanatory ability of the model. A statistical test of this conclusion is performed and accepted at the 0.05 level of significance for each model. A more intuitively appealing test is the improvement in the R^2 statistic when the production rate is added to a reduced (unit learning curve) model. Table 1 lists the R^2 full and R^2 reduced statistics side by side for each model. In each case the R^2 statistic is improved by an amount that indicates the production rate is a valuable contributor to the explanatory ability of the model.

Within some upper boundary related to plant capacity, production rate and unit labor requirements move in opposite directions with a cause and effect relationship. In every model examined, the rate variable is negatively correlated with unit direct labor requirements. This negative correlation is also reflected in the negative sign for the B_2 coefficient estimate in 13 of the 16 models (Table 1). In three KC-135A models, the combined effects of collinearity and great relative strength of the cumulative production variable causes the B_2 estimate sign to change to positive in the full model.

When comparing the effectiveness of a manufacturing or delivery rate representative of the production rate, the manufacturing rate gives better results in all six of the direct comparisons. But the difference is not great and either proxy is an important contributor to the explanatory power of the model.

The model fits fabrication hours per pound data better than assembly or total data for the F-4 and KC-135 programs. This may indicate that the fabrication labor requirements are more sensitive to production rate than the other two levels of the process examined. Fabrication and assembly hours are not evaluated for the F-102 program.

This procedure does not appear to be suited to constructing general cost models with coefficients that are applicable to other programs. The wide variation in the coefficients listed in Table 1 for models with common production levels and rates suggests that any averaging of coefficients would lead to unreliable results. The procedure appears to be suited only for predicting additional production for continuing programs.

TABLE 1

REGRESSION MODEL SUMMARY

Cost Model	Airframe Model	Cases	Level	Rate	R^2 full	R^2 reduced	B_0	B_1	B_2
1	F-4A-F	57	Total	Del	0.978	0.928	masked	-0.261	-0.169
2	F-4B-F	55	Total	Manu	0.973	0.904	"	-0.246	-0.183
3	F-4B-F	55	Total	Del	0.966	0.904	"	-0.257	-0.161
4	F-4B-F	42	Total	Manu	0.853	0.585	"	-0.230	-0.157
5	F-4B-F	42	Total	Del	0.820	0.585	"	-0.229	-0.136
6	F-4B-F	42	Fabri	Manu	0.889	0.618	6.328	-0.221	-0.148
7	F-4B-F	42	Fabri	Del	0.851	0.618	7.601	-0.219	-0.127
8	F-4B-F	42	Assem	Manu	0.744	0.658	9.016	-0.279	-0.112
9	F-4B-F	42	Assem	Del	0.733	0.658	10.400	-0.278	-0.097
10	F-102A	50	Total	Del	0.979	0.961	38.371	-0.299	-0.158
11	F-102A	42	Total	Del	0.979	0.959	47.290	-0.344	-0.144
12	KC-135A	96	Total	Dol	0.958	0.971	13.133	-0.453	0.164
13	KC-135A	7	Fabri	Manu	0.974	0.903	0.674	-0.165	-0.305
14	KC-135A	7	Fabri	Del	0.971	0.903	1.123	-0.233	-0.222
15	KC-135A	7	Assem	Manu	0.994	0.964	13.338	-0.608	0.361
16	KC-135A	7	Assem	Del	0.992	0.964	7.303	-0.527	0.263

The rate variable stabilizes and improves the predictive ability of the cost model for the F-4 and F-102 program data. This improvement is particularly marked for the nine F-4 models analyzed. The predictive accuracy of the models developed from the F-4 data sets make them attractive alternatives for estimating labor requirements for additional production. Although the model fit for the F-102A data is excellent, it does not forecast the prediction target very well. Tests for predictive ability improvement are either inconclusive or impractical for the KC-135 program data.

The procedure is well suited to forecasting the direct labor requirements for additional production lots. The steps for such a forecast are reviewed here. After the coefficients are estimated and the cost model is tailored to a particular program, one first must decide on the acceptability of the model. If the model fits, its predictive ability should be tested to gain some measure of confidence in a forecast. Assuming that the results of this test are acceptable, one must calculate the cumulative production plot point and the delivery or manufacturing rate for the unknown production lot or lots. Then using the tailored cost model, the unknown direct labor requirement for the new lot can be predicted.

The conclusions described above are necessarily limited to the data sets examined. But there is great temptation to generalize the results to other airframe production. In particular, the notion that a production rate variable correlates negatively and importantly with direct labor requirements has much application in the airframe industry if universally true.

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